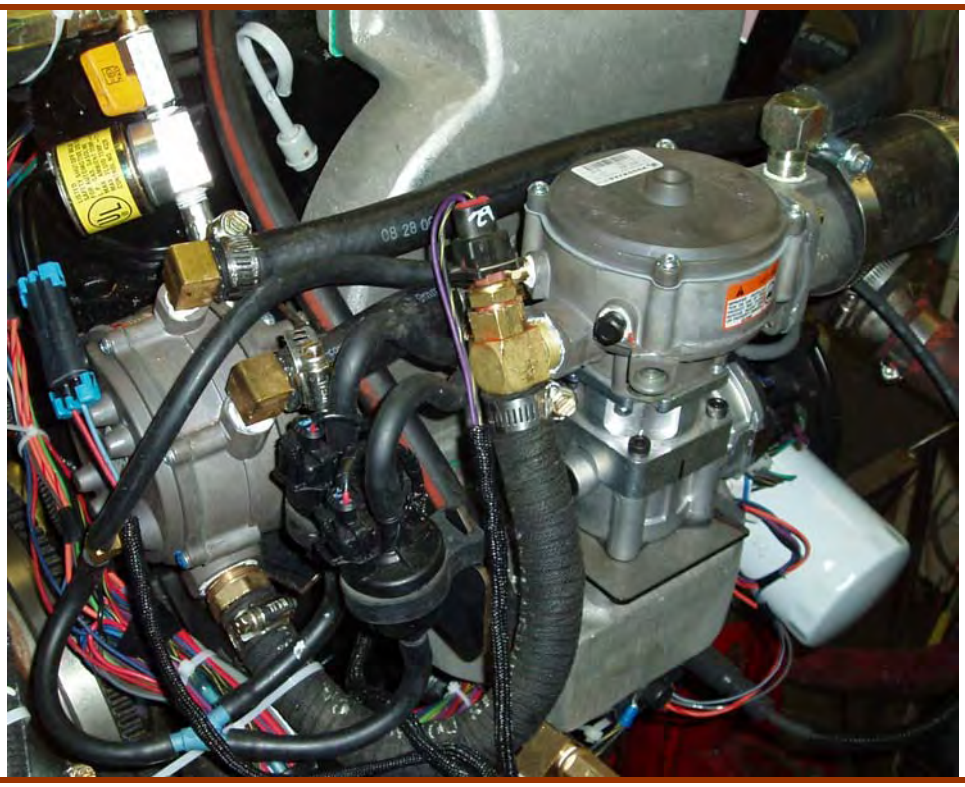
WOODWARD

Service Manual



MI-07 Integrated Engine Control System for 3.0L KEM Engines

LP & Bi-Fuel Systems

2007 Emission-Certified Systems

Manual 36553

WARNING—DANGER OF DEATH OR PERSONAL INJURY

WARNING—FOLLOW INSTRUCTIONS

Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.

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WARNING—OVERSPEED PROTECTION

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

WARNING—PROPER USE

Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.

CAUTION—POSSIBLE DAMAGE TO EQUIPMENT OR PROPERTY

CAUTION—BATTERY CHARGING

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

CAUTION—ELECTROSTATIC DISCHARGE

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts.

- **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).**
- **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.**
- **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.**

IMPORTANT DEFINITIONS

- **A WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.**
- **A CAUTION indicates a potentially hazardous situation which, if not avoided, could result in damage to equipment or property.**
- **A NOTE provides other helpful information that does not fall under the warning or caution categories.**

Revisions—Text changes are indicated by a black line alongside the text.

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Regulatory Compliance

EPA / CARB Emissions Certification

When properly applied and calibrated, Woodward's MI-07 control system is capable of meeting Environmental Protection Agency (EPA) 2007 Large Spark Ignition (LSI) emission standards (40 CFR Part 1048.101) when operating properly with an approved three-way catalyst. The emission standards, including appropriate deterioration factors over the useful life of the system, are as follows:

$HC + NO_x$: 2.0 g/hp-hr [2.7 g/kW-hr]
CO: 3.3 g/hp-hr [4.4 g/kW-hr]

Evaporative emissions comply with 40 CFR Part 1048.105. These standards apply only to volatile liquid fuels such as gasoline. Note that the engine crankcase must be closed.

As defined in applicable regulations, the engine control system is designed to maintain emissions compliance for seven (7) years or 5000 hours, whichever occurs first, provided appropriate maintenance is performed as defined in the service manual for the system. Maintenance intervals shall be defined and approved by the regulating body. Component warranty shall comply with regulatory requirements (40 CFR Part 1048.120) for all emission related components. Warranty for non-critical emissions components will be as defined in the individual purchase agreement.

North American Compliance

The N-2007 regulator is UL listed per Category ITPV LP-Gas Accessories, Automotive Type.

The N-2007 regulator and CA100 mixer have tamper-resistant features approved by the California Air Resources Board (CARB).

Special Conditions for Safe Use

Field wiring must be suitable for at least 248°F (120°C).

SECM-48 inputs are classified as permanently connected International Electrotechnical Commission (IEC) measurement Category I. To avoid the danger of electric shock, do not use inputs to make measurements within measurement categories II, III, or IV. See Woodward publication 26377, SECM-48 Manual, Chapter 2 for additional information on transient over-voltage input ratings.

SECM-48 input power must be supplied from a power supply/battery charger certified to IEC standard with a Safety Extra Low Voltage (SELV) classified output. Input power should be properly fused according to the wiring diagram in Woodward publication 26377, SECM-48 Manual.

SECM-48 inputs and outputs may only be connected to other circuits certified as SELV.

The IP-56 Ingress Protection rating of the control depends on the use of proper mating connectors. See Woodward publication 26377, SECM-48 Manual, Chapter 2: Installation—Wiring Connections, Table 2-1 for information on the proper mating connectors for use with this control.

WARNING—EXPLOSION HAZARD

Do not connect or disconnect while circuit is live unless area is known to be non-hazardous.

Substitution of components may impair suitability for Class I, Division 2, or Zone 2 applications.

Electromagnetic Compatibility (EMC)

All MI-07 active electronic components manufactured by the Woodward Governor Company have been developed and individually tested for electromagnetic compatibility using standardized industry methods under laboratory test conditions. Actual EMC performance may be adversely affected by the wiring harness design, wire routing, the surrounding structure, other EMC generating components, and other factors that are beyond the control of the Woodward Governor Company. It is the responsibility of the vehicle and/or application manufacturer to confirm that the overall system's EMC performance is in compliance with all standards that they wish to apply for their particular use.

Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).

2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.

3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.

CAUTION—ELECTROSTATIC DISCHARGE

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Chapter 1.
LPG System Overview

MI-07 General Description

Woodward's emission-certified MI-07 control system provides a complete, fully integrated engine management system that meets or exceeds 2007 emission standards for Large Spark Ignited (LSI) engines established by the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA).

The control system is applicable to naturally aspirated engines ranging in size from 1.5L to 8.1L (25 HP to 170 HP) with up to 8 cylinders running on LPG and/or gasoline in mobile industrial applications.

It provides accurate, reliable, and durable control of fuel, spark, and air over the service life of the engine in the extreme operating environment found in heavy-duty, under hood, on-engine electronic controls.

MI-07 is a closed loop system utilizing a catalytic muffler to reduce the emission level in the exhaust gas. In order to obtain maximum effect from the catalyst, an accurate control of the air fuel ratio is required. A small engine control module (SECM) uses two heated exhaust gas oxygen sensors (HEGO) in the exhaust system to monitor exhaust gas content. One HEGO is installed in front of the catalytic muffler and one is installed after the catalytic muffler.

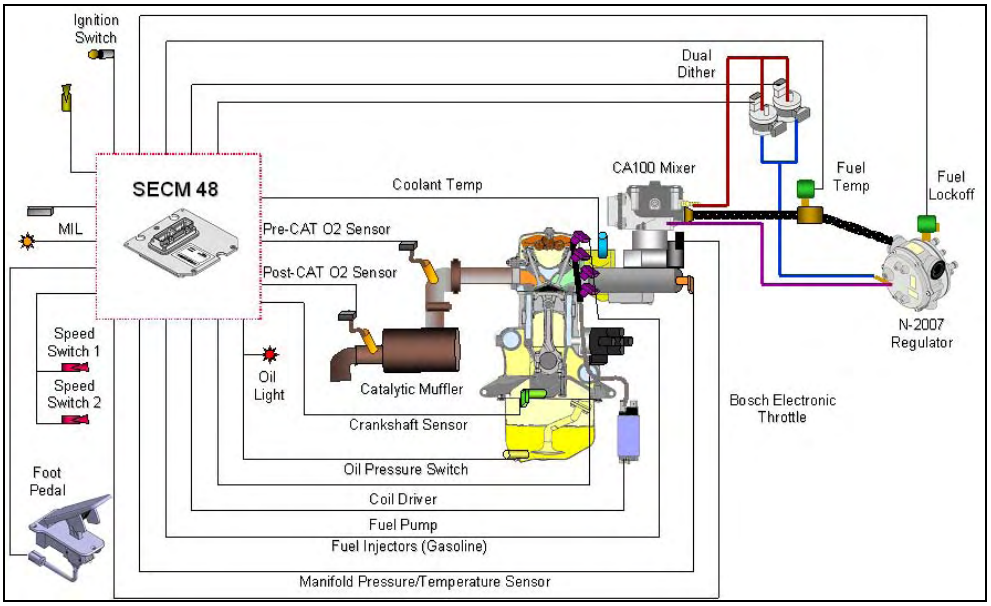


Figure 1. MI-07 Bi-Fuel System for 3.0L Engines

The SECM makes any necessary corrections to the air fuel ratio by controlling the inlet fuel pressure to the air/fuel mixer by modulating the dual fuel trim valves (FTV) connected to the regulator. Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air/fuel mixture. To calculate any necessary corrections to the air fuel ratio, the SECM uses a number of different sensors to gain information about the engine's performance. Engine speed is monitored by the SECM through a variable reluctance (VR) or Hall Effect sensor. Intake manifold air

temperature and absolute pressure are monitored with a TMAP sensor. The MI-07 system implements a drive-by-wire (DBW) system connecting the accelerator pedal to the electronic throttle through the electrical harness; mechanical cables are not used. A throttle position sensor (TPS) monitors throttle position in relation to the accelerator pedal position sensor (APP) command. Engine coolant temperature and adequate oil pressure are also monitored by the SECM. The SECM controller has full adaptive learning capabilities, allowing it to adapt control function as operating conditions change. Factors such as ambient temperature, fuel variations, ignition component wear, clogged air filter, and other operating variables are compensated.

MI-07 Closed Loop LP Fuel System

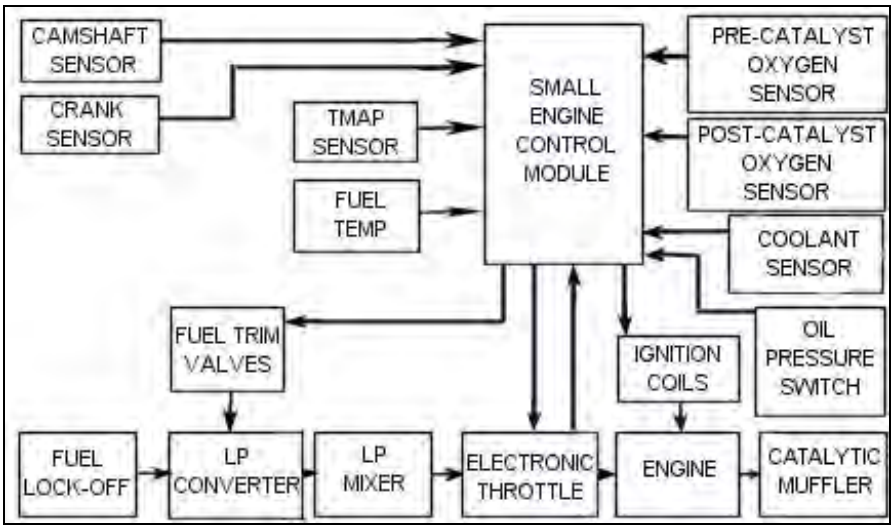


Figure 2. MI-07 Closed Loop Fuel System

MI-07 System Components

The MI-07 control system provides electronic control to the following subsystems on mobile industrial engines:

- Fuel delivery system
- Spark-ignition control system
- Air throttle
- Sensors/Switches/Speed inputs

Key Components

The MI-07 system functions primarily on engine components that affect engine emissions and performance. These key components include the following:

- Engine/Combustion chamber design
- Intake/Exhaust valve configuration, timing and lift
- Intake/Exhaust manifold design
- Catalytic converter and exhaust system
- Throttle body
- Air intake and air filter
- Gaseous fuel mixer †

- Gaseous fuel pressure regulator †
- Fuel trim valves
- Fuel trim orifices
- Small engine control module (SECM), firmware, and calibration †
- Fuel system sensors and actuators
- Ignition system including spark plugs, cables, coils and drivers
- Gasoline injectors and fuel pressure regulator (bi-fuel systems only)

(†) Components of MI-07 system manufactured by Woodward

MI-07 System Features

The MI-07 system uses an advanced speed-density control strategy for fuel, spark, and air throttle control. Key features include the following.

- Closed-loop fuel control with fuel specific controls for LPG and gasoline (MPI) fuels
- Speed-load spark control with tables for dwell, timing, and fuel type
- Speed-load throttle control with table for maximum TPS limiting
- Closed-loop fuel control with two oxygen sensors (one installed pre catalyst and one installed post catalyst). The pre-catalyst oxygen sensor includes adaptive learn to compensate for fuel or component drift. The post-catalyst oxygen sensor includes adaptive learn to compensate the pre-catalyst oxygen sensor setting for oxygen sensor drift and catalyst aging. The pre-catalyst oxygen sensor function includes parameters for transport delay, O_2 set point, excursion rich/lean, jump back rich/lean, and perturbation.
- LPG fuel temperature compensation
- Min/max speed governing
- All-speed isochronous governing
- Fixed-speed isochronous governing with three switch-selectable speeds
- Fuel enrichment and spark timing modifiers for temperature and fuel type
- Transient fuel enrichment based on rate of change of TPS
- Transient wall wetting compensation for gasoline
- Input sensor selection and calibration
- Auxiliary device control for fuel pump, fuel lock-off solenoid, tachometer, MIL, interlocks, vehicle speed limiting, etc.
- CANBus data transfer for speed, torque, etc.
- Anti-restart strategy to inhibit starter engagement while running

Other system features include:

Tamper-Resistance
Special tools, equipment, knowledge, and authorization are required to effect any changes to the MI-07 system, thereby preventing unauthorized personnel from making adjustments that will affect performance or emissions.

Diagnostics
MI-07 is capable of monitoring and diagnosing problems and faults within the system. These include all sensor input hardware, control output hardware, and control functions such as closed-loop fuel control limits and adaptive learn limits. Upon

detecting a fault condition, the system notifies the operator by illuminating the MIL and activating the appropriate fault action. The action required by each fault shall be programmable by the OEM customer at the time the engine is calibrated.

Diagnostic information can be communicated through both the service tool interface and the MIL. With the MIL, it is possible to generate a string of flashing codes that correspond to the fault type. These diagnostics are generated only when the engine is not running and the operator initiates a diagnostic request sequence such as repeated actuations of the pedal within a short period of time following reset.

Limp Home Mode
The system is capable of "limp-home" mode in the event of particular faults or failures in the system. In limp-home mode the engine speed is approximately 1000 RPM at no load. A variety of fault conditions can initiate limp-home mode. These fault conditions and resulting actions are determined during calibration and are OEM customer specific.

Service Tool
A scan tool/monitoring device is available to monitor system operation and assist in diagnosis of system faults This device monitors all sensor inputs, control outputs, and diagnostic functions in sufficient detail through a single access point to the SECM to allow a qualified service technician to maintain the system. This Mototune software (licensed by Mototron Communication) is secure and requires a crypt-token USB device to allow access to information.

Bi-Fuel System

A bi-fuel system operates on either LPG or gasoline. The engine will run on only one fuel at a time. The fuel type can be switched while the engine is stopped or running at low speeds and low loads. The fuel selection switch is a three-position type where the center position is fuel off.

Customer-Supplied Components

MI-07 requires additional components to operate that are not included with the system. These include the wire harness, mixer-to-throttle adapter, air horn adapter, mounting brackets, non-critical fittings, and hoses. These items are application specific and are the responsibility of the packager, manufacturer of record (MOR), or original equipment manufacturer (OEM). Woodward will provide assistance as needed to ensure proper fitting to the MI-07 system components.

NOTE
It is the responsibility of the customer to consult with Woodward regarding the selection or specification of any components that impact emissions, performance, or durability.

LPG Fuel System Operation

The principles outlined below describe the operation of MI-07 on an LPG fuel system.

An LPG fuel system consists of the following components:

- Fuel filter (supplied by customer)
- Electric fuel lock-off solenoid valve
- Fuel pressure regulator/vaporizer
- Two orificed fuel trim valves
- Gas/Air mixer with fixed orifice for trim system and fuel temperature sensor
- Miscellaneous customer-supplied hoses and fittings

Fuel is stored in the customer-supplied LPG tank in saturated liquid phase and enters the fuel system from the tank as a liquid and at tank pressure. Fuel passes through a high-pressure fuel filter and lock-off solenoid, and is then vaporized and regulated down to the appropriate pressure to supply the mixer. The regulator controls the fuel pressure to the gas/air mixer.

Dual Dither Valve

The key to meeting emissions requirements when operating in LPG is the dual dither valve hardware in the fuel system. Similar to the Woodward MI-04 system, the dual dither system modulates the fuel pressure regulator outlet pressure by providing an offset to the regulator secondary stage reference pressure. By adding a second dither valve, or fuel trim valve (FTV), the MI-07 system provides smoother, more accurate control of supply pressure resulting in better control of air fuel ratio and emissions. This smoother control also minimizes wear on fuel system components such as the regulator diaphragm and lever by significantly reducing the pressure pulsations observed with a single FTV.

Regulator Pressure Offset

Regulator pressure offset is achieved through the use of a fixed orifice and a variable orifice in series. The inlet to the fixed orifice is connected to a mixer port that monitors inlet air pressure (roughly equal to ambient pressure). The outlet of the fixed orifice is connected to both the pressure regulator reference port and the inlet to the two FTVs (the variable orifice) that act in parallel. The outlets of the FTVs are connected to a port at the mixer outlet, referred to as Air Valve Vacuum (AVV). Thus, by modulating the FTVs, the pressure regulator reference pressure can be varied between mixer inlet pressure and AVV. For a given change in the pressure regulator reference pressure, the pressure regulator outlet pressure changes by the same amount and in the same direction. The end result is that a change in FTV modulation changes the outlet pressure of the regulator/fuel inlet pressure of the mixer, and thus the AFR. A major benefit of this trim system results from the use of mixer inlet pressure and AVV as the reference pressure extremes. The pressure differential across the mixer fuel valve is related to these same two pressures, and thus so is fuel flow. Given this arrangement, the bias pressure delta scales with the fuel cone pressure delta. The result is that the trim system control authority and resolution on AFR stays relatively constant for the entire speed and load range of the engine.

SECM

The Small Engine Control Module (SECM) controls the LPG lock-off solenoid valve and the FTVs. The lock-off solenoid is energized when fueling with LPG and the engine is turning. FTV modulation frequency will be varied as a function of RPM by

the SECM in order to avoid resonance phenomena in the fuel system. FTV control signals will be altered by the SECM in order to maintain a stoichiometric air-fuel ratio. Control signals are based primarily on feedback from the exhaust gas oxygen sensor, with an offset for fuel temperature.

MI-07 LP Fuel Filter

After exiting the fuel tank, liquid propane passes through a serviceable inline fuel filter to the electric fuel lock off. **Figure 3** shows a typical inline type LP fuel filter manufactured by Century. The primary function of the fuel filter is to remove particles and sediments that have found their way into the tank. The LP fuel filter will *not* remove heavy end solids and paraffins that build up in LPG fuel systems as a result of vaporization.

Figure 3. Inline LP Fuel Filter

MI-07 Fuel Lock-Off (Electric)

The fuel lock-off is a safety shutoff valve normally held closed by spring pressure. It incorporates an electric solenoid and prevents fuel flow to the regulator/converter when the engine is not in operation. This is the first of three safety locks in the MI-07 system.

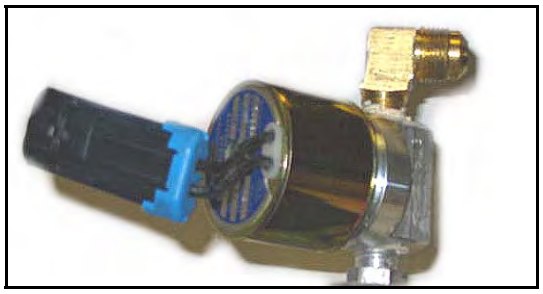


Figure 4. Electric Fuel Lock Assembly

In the MI-07 design, power is supplied to the fuel lock-off via the main power relay with the SECM controlling the lock-off ground (earth) connection. The lock-off remains in a normally closed (NC) position until the key switch is activated. This supplies power to the lock-off and the SECM, but will not open the lock-off via the main power relay until the SECM provides the lock-off ground connection. This design gives the SECM full control of the lock-off while providing additional safety by closing the fuel lock-off in the unlikely event of a power failure, wiring failure or module failure.

When the liquid service valve in the fuel container is opened, liquid propane flows through the LP filter and through the service line to the fuel lock-off. Liquid propane enters the lock-off through the 1/4” NPT liquid inlet port and stops with the lock-off in the normally closed position. When the engine is cranking, the main power relay applies power to the lock-off and the SECM provides the lock-off ground causing current to flow through the windings of the solenoid creating a magnetic field. The strength of this magnetic field is sufficient to lift the lock-off valve off of its seat against spring pressure. When the valve is open liquid propane, at tank pressure, flows

through the lock-off outlet to the pressure regulator/converter. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states: *Crank* - when the crankshaft position sensor detects any engine revolutions; *Stall* - when the key is in the ON position but the crankshaft position sensor detects no engine revolutions; and *Run* - when the engine reaches pre-idle RPM. When an operator turns on the key switch the lock-off is opened, but if the operator fails to crank the engine the SECM will close the lock-off after a number of seconds (calibration specific).

N-2007 Pressure Regulator/Vaporizer

The pressure regulator/vaporizer receives liquid LPG from the fuel storage tank, drops the pressure, changes the LPG phase from liquid to vapor, and provides vapor phase LPG at a regulated outlet pressure to the mixer. To offset the refrigeration effect of the vaporization process, the regulator will be supplied with engine coolant flow sufficient to offset the latent heat of vaporization of the LPG. A thermostat installed in the coolant supply line maintains regulator outlet coolant temperature at or below 140°F (60°C) which minimizes the deposit of fuel contaminants and heavy ends in the regulator and assures a more controlled vaporization process with reduced pressure pulsations.

A higher flow pressure regulator is required on larger engines.

Figure 5. N-2007 Regulator

The regulator is normally closed, requiring a vacuum signal (negative pressure) to allow fuel to flow. This is the second of three safety locks in the MI-07 system. If the engine stops, vacuum signal stops and fuel flow will automatically stop when both the secondary (2nd stage) valve and the primary (1st stage) valve closes. Unlike most other regulator/converters, the N-2007 primary valve closes *with* fuel pressure rather than against pressure, extending primary seat life and adding additional safety.

Liquid propane must be converted into a gaseous form in order to be used as a fuel for the engine. When the regulator receives the desired vacuum signal it allows propane to flow to the mixer. As the propane flows through the regulator the pressure is reduced in two stages from tank pressure to slightly less than atmospheric pressure. As the pressure of the propane is reduced, the liquid propane vaporizes and refrigeration occurs inside the regulator due to the vaporization of liquid propane. To replace heat lost to vaporization, engine coolant is supplied by the engine driven water pump and pumped through the regulator. Heat provided by this coolant is transferred through to the fuel vaporization chamber.

N-2007 Operation

(Refer to **Figure 6**.)
Liquid propane, at tank pressure, enters the N-2007 through the fuel inlet port (**1**). Propane liquid then flows through the primary valve (**2**). The primary valve located at the inlet of the expansion chamber (**3**), is controlled by the primary diaphragm (**4**), which reacts to vapor pressure inside the expansion chamber. Two springs are used to apply force on the primary diaphragm in the primary diaphragm chamber (**5**), keeping the primary valve open when no fuel pressure is present.

A small port connects the expansion chamber to the primary diaphragm chamber. At the outlet of the expansion chamber is the secondary valve (**6**). The secondary valve is held closed by the secondary spring on the secondary valve lever (**7**). The secondary diaphragm controls the secondary lever. When the pressure in the expansion chamber reaches 1.5 psig (10.342 kPa) it causes a pressure/force imbalance across the primary diaphragm (**8**). This force is greater than the primary diaphragm spring pressure and will cause the diaphragm to close the primary valve.

Since the fuel pressure has been reduced from tank pressure to 1.5 psig (10.342 kPa) the liquid propane vaporizes. As the propane vaporizes it takes on heat from the expansion chamber. This heat is replaced by engine coolant, which is pumped through the coolant passage of the regulator. At this point vapor propane will not flow past the expansion chamber of the regulator until the secondary valve is opened. To open the secondary valve, a negative pressure signal must be received from the air/fuel mixer. When the engine is cranking or running a negative pressure signal (vacuum) travels through the vapor fuel outlet connection of the regulator, which is the regulator secondary chamber, and the vapor fuel inlet of the mixer. The negative pressure in the secondary chamber causes a pressure/force imbalance on the secondary diaphragm, which overcomes the secondary spring force, opening the secondary valve and allowing vapor propane to flow out of the expansion chamber, through the secondary chamber to the mixer.

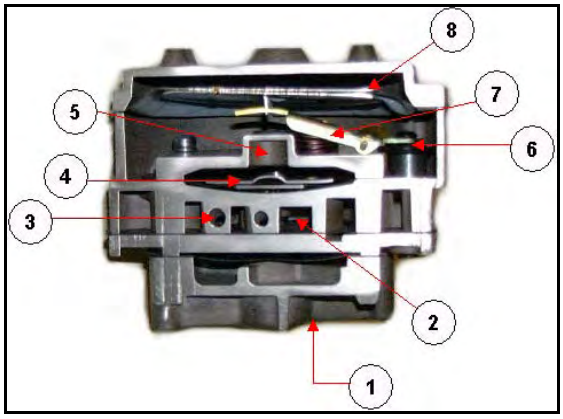


Figure 6. Parts View of N-2007 Regulator

Because vapor propane has now left the expansion chamber, the pressure in the chamber will drop, causing the primary diaphragm spring force to re-open the primary valve allowing liquid propane to enter the regulator, and the entire process starts again. This creates a balanced condition between the primary and secondary chambers allowing for a constant flow of fuel to the mixer as long as the demand from the engine is present. The fuel flow is maintained at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing will vary depending on how far the secondary valve opens in response to the negative pressure signal generated by the air/fuel mixer. The strength of that negative pressure signal developed by the mixer is directly related to the amount of air flowing through the mixer into the engine. With this process, the larger the quantity of air flowing into the engine, the larger the amount of fuel flowing to the mixer.

CA100 Mixer

The mixer is installed above the throttle body and meters gaseous fuel into the airstream at a rate that is proportional to the volumetric flow rate of air. The ratio between volumetric airflow and volumetric fuel flow is controlled by the shaping of the mixer fuel cone and biased by the controllable fuel supply pressure delivered by the pressure regulator. Fuel flow must be metered accurately over the full range of airflows. Pressure drop across the mixer air valve must be minimized to assure maximum power output from the engine.

The mixer fuel inlet is fitted with a thermistor-type temperature sensor. This permits the SECM to correct fuel pressure to compensate for variations in fuel temperature. Left uncorrected, fuel temperature variations can cause significant variations in air fuel ratio.

A higher flow mixer is required on larger engines. A lower flow mixer is required on smaller engines.

Figure 7. CA100 Mixer

CA100 Mixer Operation

Vapor propane fuel is supplied to the CA100 mixer by the N-2007 pressure regulator/converter. The mixer uses a diaphragm type air valve assembly to operate a gas-metering valve inside the mixer. The gas-metering valve is normally closed, requiring a negative pressure (vacuum) signal from a cranking or running engine to open. This is the third of the three safety locks in the MI-07 system. If the engine stops or is turned off, the air valve assembly closes the gas-metering valve, stopping fuel flow past the mixer. The gas-metering valve controls the amount of fuel to be mixed with the incoming air at the proper ratio. The air/fuel mixture then travels past the throttle, through the intake manifold and into the engine cylinders where it is compressed, ignited and burned.

Figure 8. CA100 Mixer Attached to Throttle Body

(Refer to **Figure 9**.)
The air/fuel mixer is mounted in the intake air stream between the air cleaner and the throttle. The design of the main body incorporates a cylindrical bore or mixer bore, fuel inlet (**1**) and a gas discharge jet (**2**). In the center of the main body is the air valve assembly, which is made up of the air valve (**3**), the gas-metering valve (**4**), the air valve diaphragm (**5**), and air valve spring (**6**). The gas-metering valve is permanently mounted to the air valve diaphragm assembly with a face seal mounted between the two parts.

When the engine is not running this face seal creates a barrier against the gas discharge jet, preventing fuel flow with the aid (downward force) of the air valve spring. When the engine is cranking it begins to draw in air, creating a negative pressure signal. This negative pressure signal is transmitted through four vacuum ports in the air valve.

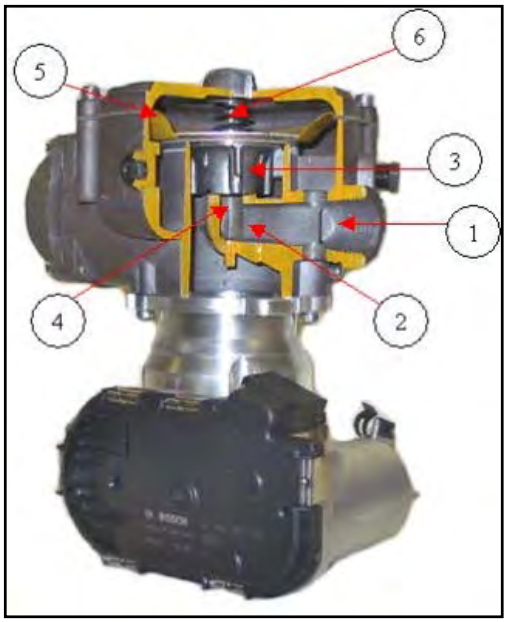


Figure 9. Parts View of CA100 Mixer

A pressure/force imbalance begins to build across the air valve diaphragm between the air valve vacuum (AVV) chamber (above the diaphragm) and atmospheric pressure below the diaphragm. Approximately 6 inches H_2O (14.945 mbar) of negative pressure is required to overcome the air valve spring force and push the air valve assembly upward off the valve seat. Approximately 24 inches H_2O (59.781 mbar) pulls the valve assembly to the top of its travel in the full open position.

The amount of negative pressure generated is a direct result of throttle position and the amount of air flowing through the mixer to the engine. At low engine speeds, low AVV causes the air valve diaphragm assembly to move upward a small amount, creating a small venturi. At high engine speeds, high AVV causes the air valve diaphragm assembly to move much farther creating a large venturi. The variable venturi air/fuel mixer constantly matches venturi size to engine demand.

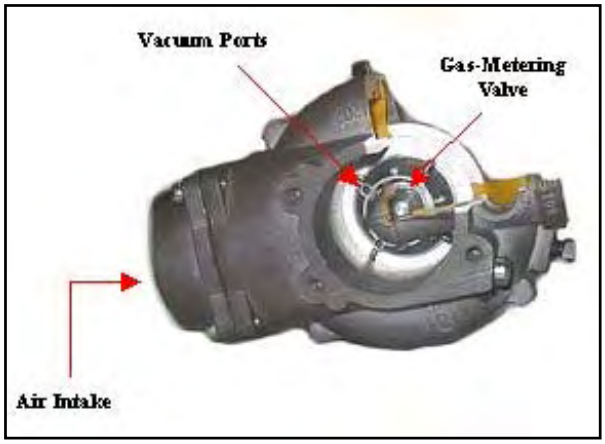


Figure 10. Bottom View of Air Valve Assembly

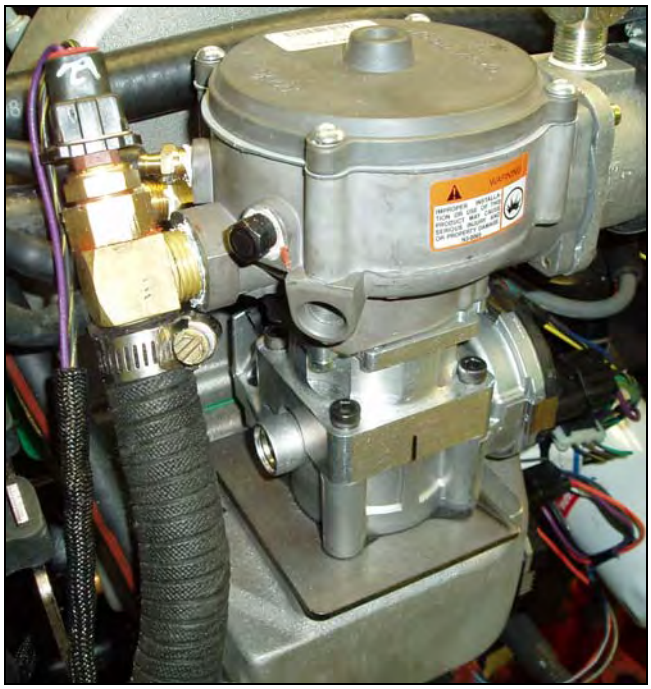


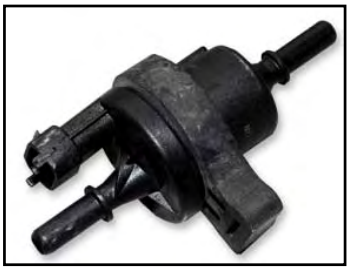
Figure 11. CA100 Mixer Installed with Electronic Throttle

A main mixture adjustment valve on the fuel inlet of the CA100 is not available in the MI-07 system, however an idle mixture adjustment is incorporated into the mixer (**Figure 12**). The idle mixture adjustment is an air bypass port, adjusting the screw all the way in, blocks off the port and enriches the idle mixture. Backing out the idle adjustment screw opens the port and leans the idle mixture. The idle mixture screw is a screw with locking threads that is factory set with a tamper resistant cap installed after adjustment. Accurate adjustment of the idle mixture can be accomplished by adjusting for a specific fuel trim valve (FTV) duty cycle with the Service Tool software or with a voltmeter. **NOTE: Adjustments should only be performed by trained service technicians.**

Figure 12. Idle Mixture Adjustment Screw

Fuel Trim Valve (FTV)

The Fuel Trim Valve (FTV) is a two-way electric solenoid valve and is controlled by a pulse-width modulated (PWM) signal provided by the SECM. Two FTVs are used to bias the output fuel pressure on the LPG regulator/converter (N-2007), by metering air valve vacuum (AVV) into the atmospheric side of the N-2007 secondary regulator diaphragm. An orifice balance line connected to the air inlet side of the mixer provides atmospheric reference to the N-2007 when the FTVs are closed. The SECM uses feedback voltage from the O_2 sensor to determine the amount of bias needed to the regulator/converter.



In normal operation the N-2007 maintains fuel flow at a constant output pressure, due to the calibrated secondary spring. The amount of fuel flowing from the N-2007 will vary depending on how far the secondary diaphragm opens the secondary valve in response to the negative pressure signal generated by the air/fuel mixer. One side of the N-2007 secondary diaphragm is referenced to FTV control pressure while the other side of the diaphragm reacts to the negative pressure signal from the mixer. If the pressure on the reference side of the N-2007 secondary diaphragm is reduced, the diaphragm will close the secondary valve until a balance condition exists across the diaphragm, reducing fuel flow and leaning the air/fuel mixture.

Branch-Tee Fitting

A branch-tee fitting is installed in the atmospheric vent port of the N-2007 with one side of the branch-tee connected to the intake side of the mixer forming the balance line and referencing atmospheric pressure. The other side of the branch-tee fitting connects to the FTV inlet (small housing side). The FTV outlet (large housing connector side) connects to the AVV port. When the FTVs are open AVV is sent to the atmospheric side of the N-2007 secondary diaphragm, which lowers the reference pressure, closing the N-2007 secondary valve and leaning the air/fuel mixture. The MI-07 system is calibrated to run rich without the FTVs. By modulating (pulsing) the FTVs the SECM can control the amount of AVV applied to the N-2007 secondary diaphragm. Increasing the amount of time the FTVs remain open (modulation or duty cycle) causes the air/fuel mixture to become leaner; decreasing the modulation (duty cycle) enriches the mixture.

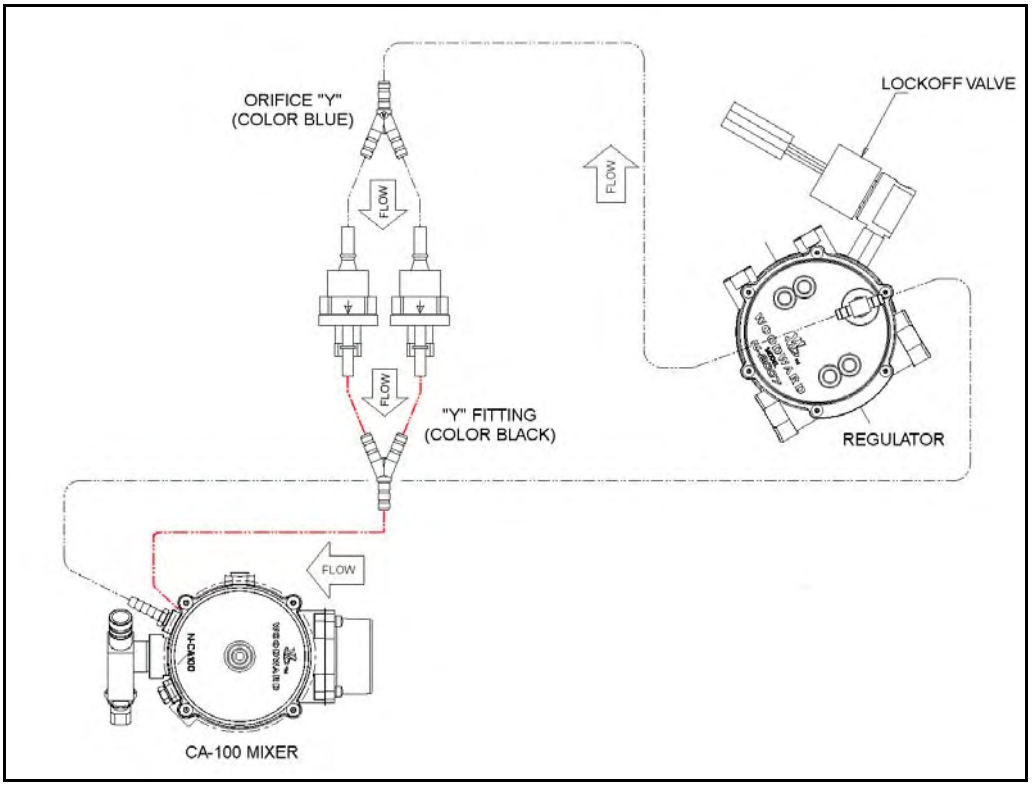


Figure 13. Fuel Trim Valves Connected to MI-07 System

Electronic Throttle System

The electronic throttle system controls engine output (speed and torque) through electronic control of mass airflow to the engine. Any DC motor-actuated or Limited Angle Torque motor (LAT)-actuated throttle with less than 5A peak and 2A steady state can be controlled. The TPS must be directly coupled to the throttle shaft for direct shaft position measurement.

A commonly used throttle is the Bosch DV-E5. This throttle is available in a variety of bore sizes to meet specific engine needs: 32mm, 40mm, and 54mm are readily available throttle bore sizes; other sizes are possible. The Bosch throttle is a fully validated automotive component incorporating a brushed DC motor with gear reduction, dual throttle position sensors, throttle plate, and cast aluminum housing. In the event of an electrical disconnection or other related failure, the throttle plate returns to a limp-home idle position at a no-load engine speed above curb idle speed. This provides sufficient airflow for the engine to move the vehicle on level ground. Any throttle bodies used for MI-07 meet or exceed the specification for the Bosch throttle bodies.

In terms of response, the throttle is capable of fully opening and closing in less than 50 msec. Position resolution and steady state control should be 0.25% of full travel or better.

MI-07 Electronic Throttle

Conventional throttle systems rely on a mechanical linkage to control the throttle valve. To meet fluctuating engine demands a conventional system will typically include a throttle valve actuator designed to readjust the throttle opening in response to engine demand, together with an idle control actuator or idle air bypass valve.

In contrast, the MI-07 system uses electronic throttle control (ETC). The SECM controls the throttle valve based on engine RPM, engine load, and information received from the foot pedal. Two potentiometers on the foot pedal assembly monitor accelerator pedal travel. The electronic throttle used in the MI-07 system is a Bosch 32mm or 40mm electronic throttle body DV-E5 (**Figure 14**). The DV-E5 is a single unit assembly, which includes the throttle valve, throttle-valve actuator (DC motor) and two throttle position sensors (TPS). The SECM calculates the correct throttle valve opening that corresponds to the driver's demand, makes any adjustments needed for adaptation to the engine's current operating conditions and then generates a corresponding electrical (driver) signal to the throttle-valve actuator.

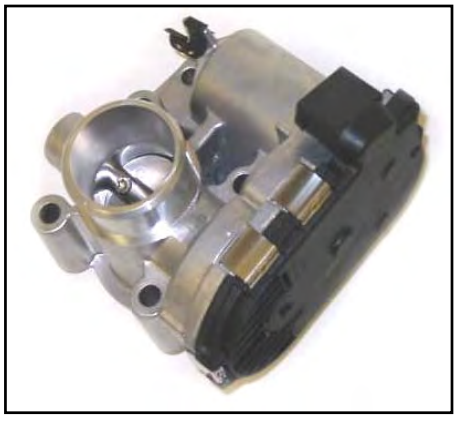
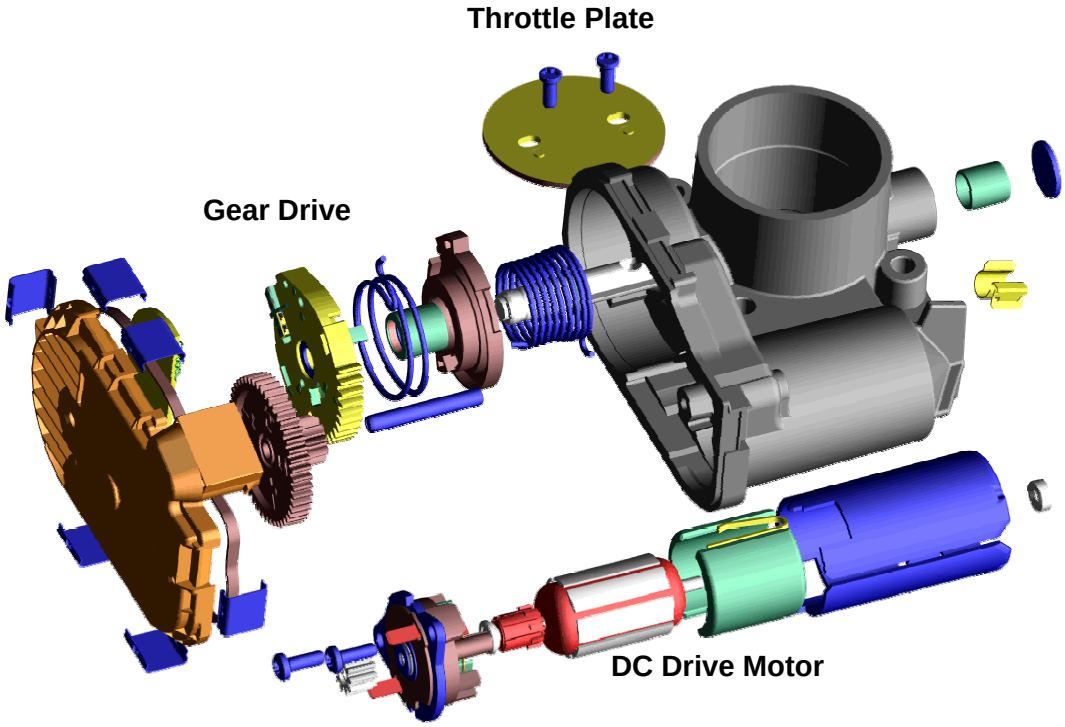


Figure 14. Bosch Electronic Throttle Body

The MI-07 uses a dual TPS design (TPS_1 and TPS_2). The SECM continuously checks and monitors all sensors and calculations that effect throttle valve position whenever the engine is running. If any malfunctions are encountered, the SECM's initial response is to revert to redundant sensors and calculated data. If no redundant signal is available or calculated data cannot solve the malfunction, the SECM will drive the system into one of its limp-home modes or shut the engine down, storing the appropriate fault information in the SECM.

There are multiple limp-home modes available with electronic throttle control:

1. If the throttle itself is suspected of being inoperable, the SECM will remove the power to the throttle motor. When the power is removed, the throttle blade returns to its "default" position, approximately 7% open.
2. If the SECM can still control the throttle but some other part of the system is suspected of failure, the SECM will enter a "Reduced Power" mode. In this mode, the power output of the engine is limited by reducing the maximum throttle position allowed.
3. In some cases, the SECM will shut the engine down. This is accomplished by stopping ignition, turning off the fuel, and disabling the throttle.



Picture courtesy of Robert Bosch GmbH

Figure 15. Throttle Body Assembly Exploded View

Ignition System

Spark-ignited engines require accurate control of spark timing and spark energy for efficient combustion. The MI-07 ignition system provides this control. The system consists of the following components:

- SECM
- Ignition coil(s) *
- Crankshaft position sensor *
- Crankshaft timing wheel *
- Cam position sensor *
  (for sequential ignition or fuel injection only)
- Cam timing wheel *
  (for sequential ignition or fuel injection only)
- Spark plugs *

(*) Customer-supplied components

The SECM, through use of embedded control algorithms and calibration variables, determines the proper time to start energizing the coil and fire the spark plug. This requires accurate crank/camshaft position information, an engine speed calculation, coil energy information, and target spark timing. The SECM provides a TTL compatible signal for spark control. The coil must contain the driver circuitry necessary to energize the primary spark coil otherwise an intermediary coil driver device must be provided. The SECM controls spark energy (dwell time) and spark discharge timing.

General Motors (GM) High Voltage Switch (HVS) System

The GM 3.0L engine has a distributed ignition system comprised of one coil and a distributor driven from the engine camshaft. The camshaft rotates at half the speed of the engine thereby guaranteeing that each spark plug will fire once for every two revolutions of the engine.

The GM HVS system provides a control interface that allows external control modules to control engine timing and dwell. When the SECM sends a 5-volt signal to the control interface, the coil control module begins charging the coil. When the SECM signal returns to the ground state, the coil discharges into the distributor, which directs the charge to the appropriate spark plug. In this way, the amount of time the SECM signal is in the high state determines the coil dwell. The moment that the signal returns to the ground state determines when the spark plug fires.

The spark timing cannot be altered by rotating the distributor. The SECM uses the crankshaft position sensor to determine the ignition timing, so changing the position of the distributor will have no effect on the timing.

IGNITION SYSTEM COMPONENTS

In a typical distributed ignition system, a crankshaft position sensor generates a basic timing signal by reading notches on the crankshaft, flywheel, or harmonic balancer. The crank sensor signal goes to the small engine control module (SECM), where it is used to turn the ignition coil on and off via the GM HVS control interface.

The operation of the ignition system is essentially the same as any other ignition system. The coil has a low primary resistance (0.4 to 0.6 ohms) and steps up the

primary system voltage from 12 volts to as much as 40,000 volts to produce a spark for the spark plug. The distributor assures that the voltage is directed to the spark plug of the proper cylinder. Resistor spark plugs are generally used to suppress electromagnetic interference (EMI).

MISFIRES

Common ignition system ailments include misfiring, hard starting, or a no start. Spark plugs can still be fouled by oil or fuel deposits, as well as pre-ignition and detonation.

If the crankshaft position sensor fails, the loss of the basic timing signal will prevent the system from generating a spark and the engine will not start or run. A failed driver circuit within the SECM will also prevent proper ignition system operation.

It is important to remember that ignition misfire can also be caused by other factors such as worn or fouled spark plugs, loose or damaged coil connector or terminals, dirty fuel injectors, low fuel pressure, intake vacuum leaks, loss of compression in a cylinder, or even contaminated fuel. These other possibilities should all be ruled out before the distributor control module is replaced.

A SECM controlled engine that cranks but fails to start, in many cases, will often have a problem in the crankshaft or camshaft position sensor circuits. Loss of sensor signals may prevent the SECM from properly synchronizing, thereby preventing the engine from starting and running.

IGNITION SYSTEM CHECKS

The ignition coil can be tested with an ohmmeter. Measure primary and secondary resistance and compare to specifications. If resistance is out of specifications, the coil is bad and needs to be replaced.

Also, pay close attention to the tube that wraps around the spark plug. Cracks can allow voltage to jump to ground causing a misfire. The spark plug terminal should also fit tightly.

If a coil tests bad and is replaced, cleaning the connector and wiring harness terminals of the coil and distributor can often avoid future problems. Corrosion at either place can cause intermittent operation and loss of continuity, which may contribute to component failure. Applying dielectric grease to these connections can help prevent corrosion and assure a good electrical connection.

Magnetic crankshaft position sensors can be tested with an ohmmeter, and the sensor output voltage and waveform can be read with an oscilloscope. The variable reluctance crankshaft position sensor can be checked with an ohmmeter. The resistance of the sensor should be greater than 100Ω and less than 100kΩ. On most vehicles, a defective crank position sensor will usually set a fault code that can be read with the Service Tool.

Exhaust System

Heated Exhaust Gas Oxygen Sensors (HEGO)

The MI-07 system utilizes two HEGO (O_2) sensors. One sensor is a pre-catalyst sensor that detects the amount of oxygen in the exhaust stream and is considered the primary control point. Based upon the O_2 sensor feedback, the MI-07 system supplies a stoichiometric air-fuel ratio to the catalytic converter. The catalytic converter then reduces emissions to the required levels. The second sensor is a post-catalyst sensor that detects the amount of oxygen after the catalyst. This sensor is used as a secondary control point to adjust the pre-catalyst setpoint to ensure proper catalyst conversion efficiency.

Once a HEGO sensor reaches approximately 600°F (316°C), it becomes electrically active. The concentration of oxygen in the exhaust stream determines the voltage produced. If the engine is running rich, little oxygen will be present in the exhaust and voltage output will be relatively high. Conversely, in a lean situation, more oxygen will be present and a smaller electrical potential will be noticed.

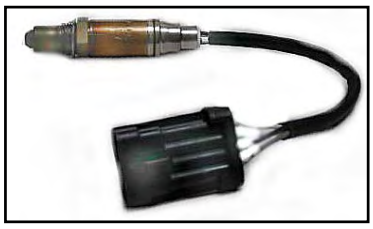


Figure 16. HEGO (O_2) Sensor

In order for the sensor to become active and create an electrical signal below 600°F (316°C) a heated element is added to the sensor housing. Two wires provide the necessary 12 Vdc and ground signal for the heater element. A fourth wire provides an independent ground for the sensor. The pre-catalyst sensor heater is powered by the main power relay and is always powered. The post-catalyst sensor heater is powered from an additional relay that is controlled by the SECM. This relay is only energized when the SECM calculates that water condensation in the exhaust system and catalytic muffler prior to the sensor should be evaporated. This is to avoid thermal shock of the sensor that could prematurely fail the sensor.

The HEGO stoichiometric air-fuel ratio voltage target is approximately 500 mV and changes slightly as a function of speed and load. When the pre-catalyst HEGO sensor sends a voltage signal less than 450 mV the SECM interprets the air-fuel mixture as lean. The SECM then decreases the PWM duty cycle sent to the fuel trim valves in order to increase the fuel pressure to the mixer inlet; thus richening air-fuel mixture. The opposite is true if the SECM receives a voltage signal above 450 mV from the HEGO. The air-fuel mixture would then be interpreted as being too rich and the SECM would increase the duty cycle of the trim valves.

CAUTION
The HEGO sensors are calibrated to work with the MI-07 control system. Use of alternate sensors may impact performance and the ability of the system to diagnose rich and lean conditions.

Catalytic Muffler

In order to meet 2007 emission requirements a 3-way catalyst is necessary.

The MI-07 control system monitors the exhaust stream pre and post catalyst and uses this information to control the air-fuel mixture. By using the signals from the HEGOs, the SECM can increase or decrease the amount of oxygen in the exhaust by modulating the FTVs and adjusting the air-fuel ratio. This control scheme allows the

SECM to make sure that the engine is running at the correct air to fuel ratio so that the catalyst can perform as required to meet the emissions certification.

SECM

The Woodward Small Engine Control Module (SECM) controller has full authority over spark, fuel and air. Utilizing a Freescale micro controller, the SECM has 48 pins of I/O and is fully waterproof and shock hardened. To optimize engine performance and drivability, the SECM uses several sensors for closed loop feedback information. These sensors are used by the SECM for closed loop control in three main categories:

- Fuel Management
- Load/Speed Management
- Ignition Management

The SECM monitors system parameters and stores any out of range conditions or malfunctions as faults in SECM memory. Engine run hours are also stored in memory. Stored fault codes can be displayed on the Malfunction Indicator Light (MIL) as flash codes or read by the MI-07 Service Tool software through a Controller Area Network (CAN) communication link.

Constant battery power (12 Vdc) is supplied through the fuse block to the SECM and the main power relays. Upon detecting a key-switch ON input, the SECM will fully power up and energize the main power relays. The energized main power relays supply 12 Vdc power to the heated element of the oxygen sensors, fuel lock-off, fuel trim valves (FTVs), gasoline injectors, gasoline fuel pump, crank sensor, cam sensor, and the ignition coils. The SECM supplies voltage to the electronic throttle actuator, oil pressure switch, fuel temperature sensor, and the coolant temperature sensor. Transducer or sensor power (+ 5 Vdc) is regulated by the SECM and supplied to the manifold temperature/air pressure (TMAP) sensor, throttle position sensor (TPS), and the accelerator pedal position sensors (APP_1 & APP_2). The SECM provides a transducer ground for all the sensors, and a low side driver signal controlling the fuel lock-off, MIL, gasoline injectors, gasoline fuel pump, and FTVs.

Fuel Management

During engine cranking at startup, the SECM provides a low side driver signal to the fuel lock-off, which opens the lock-off allowing liquid propane to flow to the N-2007 regulator. A stall safety shutoff feature is built into the SECM to close the lock-off in case of a stall condition. The SECM monitors three engine states:

Crank, when the crankshaft position sensor detects any engine revolutions

Stall, when the key is in the ON position but the crankshaft position sensor detects no engine revolutions

Run state, when the engine reaches a calibration specific RPM.

When an operator turns on the key switch the lock-off is opened but if the operator fails to crank the engine, the SECM will close the lock-off after a calibration specific number of seconds.

To maintain proper exhaust emission levels, the SECM uses a heated exhaust gas oxygen sensor (HEGO) mounted before the catalyst, to measure exhaust gas content in the LP gas system. Engine speed is monitored by the SECM through a variable reluctance (VR) sensor or Hall-Effect type sensor. Intake manifold air temperature and absolute pressure are monitored with a (TMAP) sensor. The HEGO voltage is converted to an air/fuel ratio value. This value is then compared to a target value in the SECM. The target value is based on optimizing catalyst efficiency for a given load and speed. The SECM then calculates any corrections that need to be made to the air/fuel ratio.

The system operates in open loop fuel control mode until the engine has done a certain amount of work. This ensures that the engine and HEGO are sufficiently warmed up to stay in control. In open loop control mode, the FTV duty cycle is based on engine speed and load. Once the HEGO reaches operating temperature the fuel management is in closed loop control mode for all steady state conditions, from idle through full throttle. In closed loop mode, the FTV duty cycle is based on feedback from the HEGO sensor. The system may return to open-loop operation when engine load or engine speed vary beyond a chosen threshold.

The SECM makes any necessary corrections to the air-fuel ratio by controlling the inlet fuel pressure to the air-fuel mixer Reducing the fuel pressure leans the air/fuel mixture and increasing the fuel pressure enriches the air-fuel mixture. Control is achieved by modulating the fuel trim valves.

Throttle Management

Drive-by-wire (DBW) refers to the fact that the MI-07 control system has no mechanical linkage from the operator to the throttle body. Instead, the SECM controls the throttle based on input commands such as foot pedals, speed select switches, or even CAN messages. The SECM monitors the input command request and controls the throttle plate by driving a DC motor connected to the throttle. The DC motor rotates the throttle plate to correspond to the requested load by the operator. The SECM will override the torque request based on governor configuration and engine safety protocols.

The use of electronic throttle control (ETC) ensures that the engine receives only the correct amount of throttle opening for any given situation, greatly improving idle quality and drivability.

Two throttle position sensors (TPS_1 and TPS_2), which are integral to the DBW throttle assembly, provide feedback for position control by monitoring the exact position of the throttle valve. See **Figure 18.**

SECM self-calibration and “cross checking” compares both signals and then checks for errors.

Figure 17. Foot Pedal

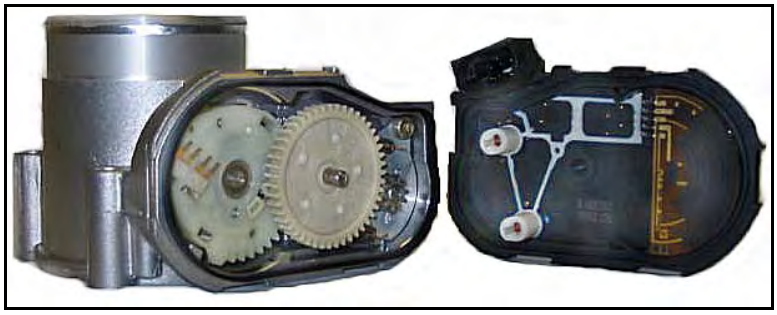


Figure 18. Throttle Position Sensor (TPS) on DV-E5 Throttle

NOTE
The DV-E5 throttle is not a serviceable assembly. If a TPS sensor fails, the assembly should be replaced.

Engine Speed Governing Modes

For idle speed control, the idle speed is driven by the SECM. Unlike a mechanical system, the idle speed is not adjustable by the end user. The idle speed is adjusted by the SECM based on engine coolant temperature. At these low engine speeds, the SECM uses spark and throttle to maintain a constant speed regardless of load.

The system governs engine speed through two modes:

1. Accelerator Pedal Position (APP)
2. All Speed Governor

ACCELERATOR PEDAL POSITION (APP)

In APP mode, the MI-07 system has minimum and maximum speed governing through the SECM and DBW throttle. This mode provides automatic *minimum speed governing* at a specified idle speed and *maximum speed governing* at a specified rated speed. In between these speeds is a manufacturer defined pedal follower function. The pedal vs.TPS request table is manufacturer configurable to provide smooth, seamless drivability.

The MI-07 system eliminates the need for air velocity governors. This substantially increases the peak torque and power available for a given system as shown in **Figure 19**. When the engine speed reaches the max governing point the speed is controlled by closing the DBW throttle. Using the DBW throttle as the primary engine speed control allows for a smooth transition into and out of the governor. If excessive over speed is detected, the engine is shut down.

MI-07 System 3.0L LPG & Gasoline Performance Curves

Figure 19. Peak Torque and Power Available with MI-07 System

ALL SPEED GOVERNOR

This function allows the operator to control the engine through an isochronous governor strategy within the torque limits of the engine. The speed set point can be configured by the manufacturer for the engine operating range.

The set point for the governor can be foot pedal, speed select switches, or CAN message (J1939 PGN [0000] [TSC1] SPN898). These modes can be individually selectable.

Drive-By-Wire Signal Flow Process

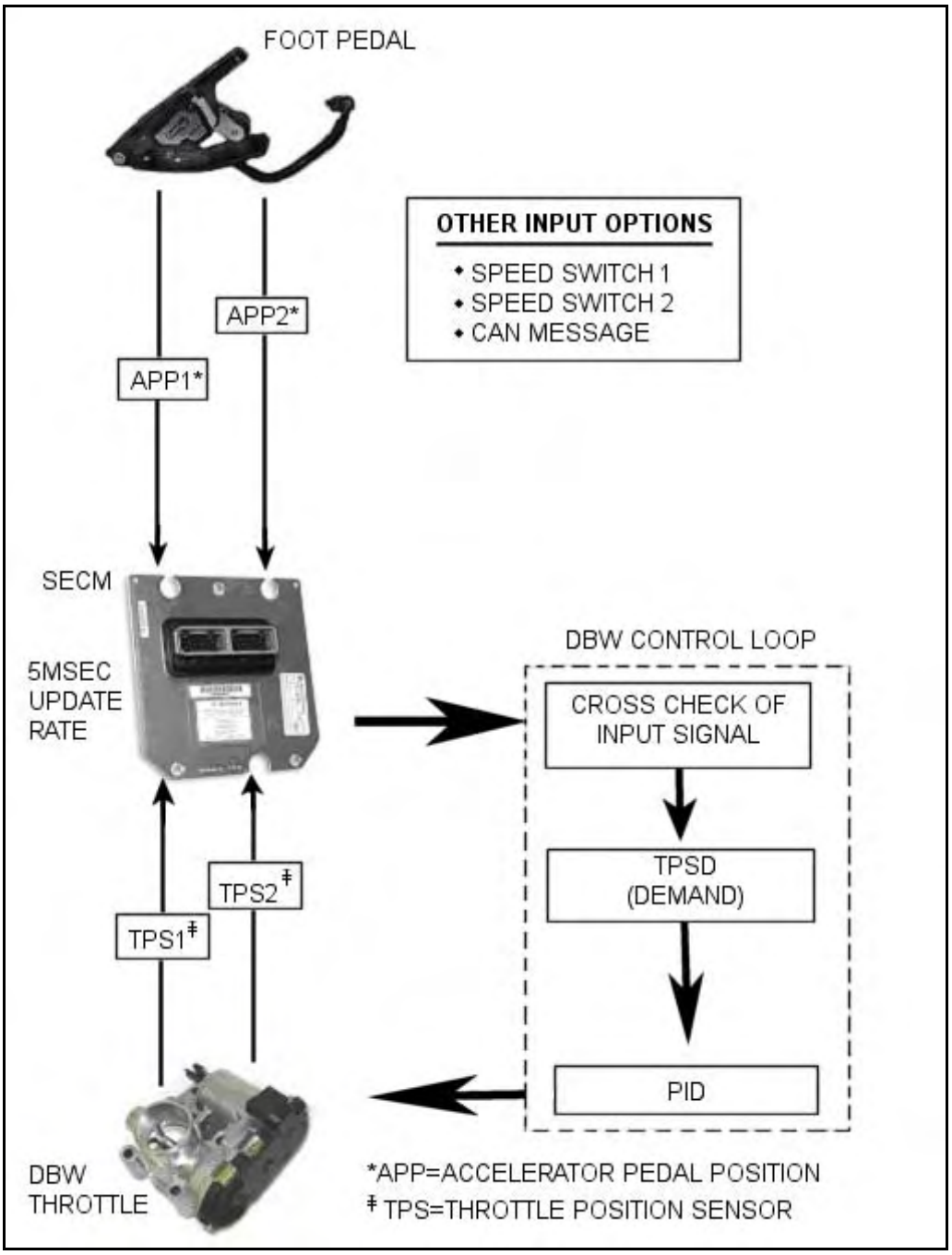


Figure 20. Drive-By-Wire Signal Flow Process

Figure 20 describes the signal flow process of the MI-07 DBW section. The foot pedal assembly uses two potentiometers to detect pedal position. These two signals, accelerator pedal position 1 (APP_1) and accelerator pedal position 2 (APP_2) are sent directly to the SECM. The SECM uses a series of algorithms to self calibrate and cross check the input signals. A demand position for the throttle will then be derived and sent to the throttle as a throttle position sensor demand (TPSd). This signal will be processed through a PID (Proportional, Integral, Derivative) controller in the SECM to achieve the appropriate motor-current response then passed to the throttle. The throttle moves to the commanded position and provides a feedback signal from the throttle position sensors (TPS_1 and TPS_2) to the SECM.

Ignition Management

In the normal course of events, with the engine operating at the correct temperature in defined conditions, the SECM will use load and engine speed to derive the correct ignition timing. In addition to load and speed there are other circumstances under which the SECM may need to vary the ignition timing, including low engine coolant temperature, air temperature, start-up, and idle speed control.

SECM Electrical Mounting Recommendations

In order to prevent the possibility of any SECM malfunctions due to EMI/RFI emissions, engine packagers and OEMs should follow industry “best practices” and the SECM mounting and harness recommendations listed below:

- The SECM should be mounted in a location that minimizes the amount of EMI the module is exposed to by locating it as far as practical from all high tension components, such as ignition coils, distributors, spark plug wires, etc. It is recommended that the SECM be mounted at least 29.5” (749 mm) away from the distributor and ignition coil, and at least 20” (508 mm) from the nearest plug wire.
- All wiring harnesses should be routed to minimize coupling (both radiated and conducted), and be securely fastened to minimize movement and maintain proper clearance between the SECM and all ignition system components.
- The OEM must ensure that a high-quality ground connection between the SECM and battery negative (–) is provided and can be maintained for the useful life of the vehicle. This may require the use of star-type washers on all ground lug connections between the SECM and the battery and/or special preparation of all mating surfaces that complete the ground connection in order to ensure that the connection is sound.

Engineering judgment must be exercised on all applications to determine if appropriate measures have been implemented to minimize EMI exposure to the SECM and associated cabling. The above recommendations do not provide any guarantee of proper system performance.

SECM / Sensors

The 48-pin Small Engine Control Module (SECM) and sensors provide the computational power, algorithm logic, sensor inputs and control outputs to control the system. The SECM receives signals from the sensors, digitizes these signals, and then, through algorithms and calibration maps, computes the desired output response to effect control of fuel, spark and air to the engine. The SECM also provides a variety of other functions and features. These include system monitoring and diagnostics to aid in maintaining efficient system operation and auxiliary control.

SECM/sensor inputs and control output specifications are specific to the application, but include a selection of the following:

Analog Inputs

The 48-pin SECM is equipped with sufficient analog inputs for the following sensors.

- **Manifold Absolute Pressure (MAP**) 1bar MAP, 0 to 5 V
- **Manifold Air Temperature (MAT)**
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kΩ to 85 Ω sensor range
- **Throttle Position Sensor 1&2 (TPS1 & TPS2)** 0 to 5 V
- **Foot Pedal Position 1&2 (FPP1 & FPP2)** 0 to 5 V
- **Coolant Temperature Sensor (CTS**)
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kΩ to 85 Ω sensor range
- **Fuel Temperature Sensor (FTS)**
  -40°F to 266°F (-40ºC to 130ºC) range, 48 kΩ to 57 Ω sensor range
- **HEGO (3)** 0 to 1 V
- **Auxiliary Analog Input (2)** 0 to 5 V
- **Battery Voltage (Vbatt) (1)** 8-18 V

With the exception of battery voltage, all inputs are 0-5 Vdc, ground referenced. Resolution should be 0.1% or better. Accuracy should be 2% or better.

Frequency/Position Inputs

- **Crankshaft position**
  Variable reluctance (2-wire, 200 V_{pp} max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors
  Permits speed resolution of 0.25 RPM and crankshaft position resolution of 0.5º
- **Camshaft position**
  Variable reluctance (2-wire, 200 V_{pp} max) or 0-5 V Hall Effect with calibration selectable pull-up resistor for open collector sensors

Digital Inputs

- **Oil pressure switch**
  Normally open, internal pull-up resistor provided to detect external switch to ground
- **Fuel select switch**
  Three-position switch for bi-fuel applications to detect gasoline mode, LPG mode, and fuel off (center switch position)

- **Ground speed select switch**
  Permits selecting two different maximum engine speeds
- **Vswitched**
  Switched battery voltage
- **Can Input**
  Governs requested speed
- **Speed Switch Input**
  Two-position switch for RPM governing

Outputs

- **Saturated injector drivers (4)**
  10A peak, 45 V max, 1 injector per channel capable of continuous on-time. Driver circuit designed for minimum turn-on/turn-off delay. Minimum pulse width resolution of 1 µsec
- **FTV drivers (2)**
  10A peak, 45V max. To drive an on/off fuel trim valve with a minimum impedance of 5 ohms. Capable of continuous on-time. Drive circuit designed for minimum turn-on /turn-off delay. FTVs will be pulse width modulated between 8 and 40 Hz with a minimum pulse width resolution of 50 µsec
- **Fuel lock-off solenoid valve**
  Low side switch, 10A peak, 4A continuous 45 V max.
- **Gasoline fuel pump drive**
  Low side switch, 10A, 4A continuous 45 V max.
- **Electronic Spark Timing (EST) (4)**
  TTL compatible outputs. Software configured for distributed ignition system
- **Throttle control (1)**
  H-Bridge, 5A peak, 2.5A continuous at 2500 Hz PWM includes current feedback for diagnostic purposes
- **MIL (Malfunction Indicator Lamp)**
  Low side switch, sufficient to drive a 7W incandescent lamp continuously
- **CANBus**
  CAN 2.0b serial communication for J1939 communications, programming, and diagnostics. Requires proper termination resistance per CAN 2.0b
- **Crank Defeat Relay**
  Stops starter from engaging while engine is running
- **Post-Cat O_2 Sensor Heater Relay**
  Turns on heater to prevent oxygen sensor damage during warmup
- **Check Engine Lamp**
  User-configurable warning lamp

SECM-48 Wiring Diagrams

CAUTION—PROPER WIRING
To prevent system faults be sure to follow good wiring practices. Poor wiring may cause unexpected or intermittent failures not related to MI-07 components.

NOTE
Always refer to MOR-furnished wiring diagrams for your specific application.

The schematics on the next pages are wiring diagrams for all types of 3.0L engine systems.

Figure 21: Bi-fuel system

Figure 22: LP system

Figure 23: Gasoline system

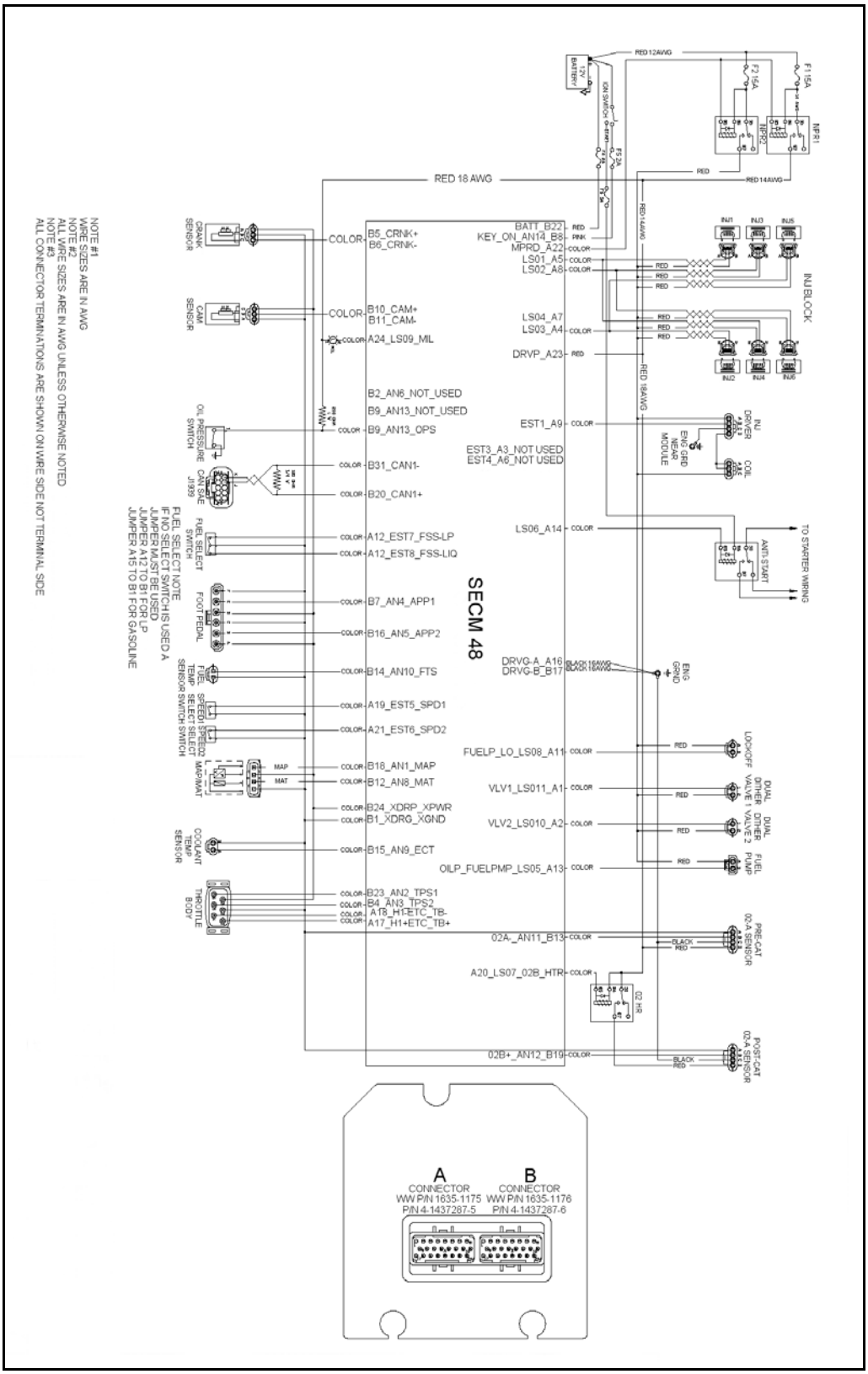


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Figure 21. SECM Wiring Diagram for Bi-Fuel System

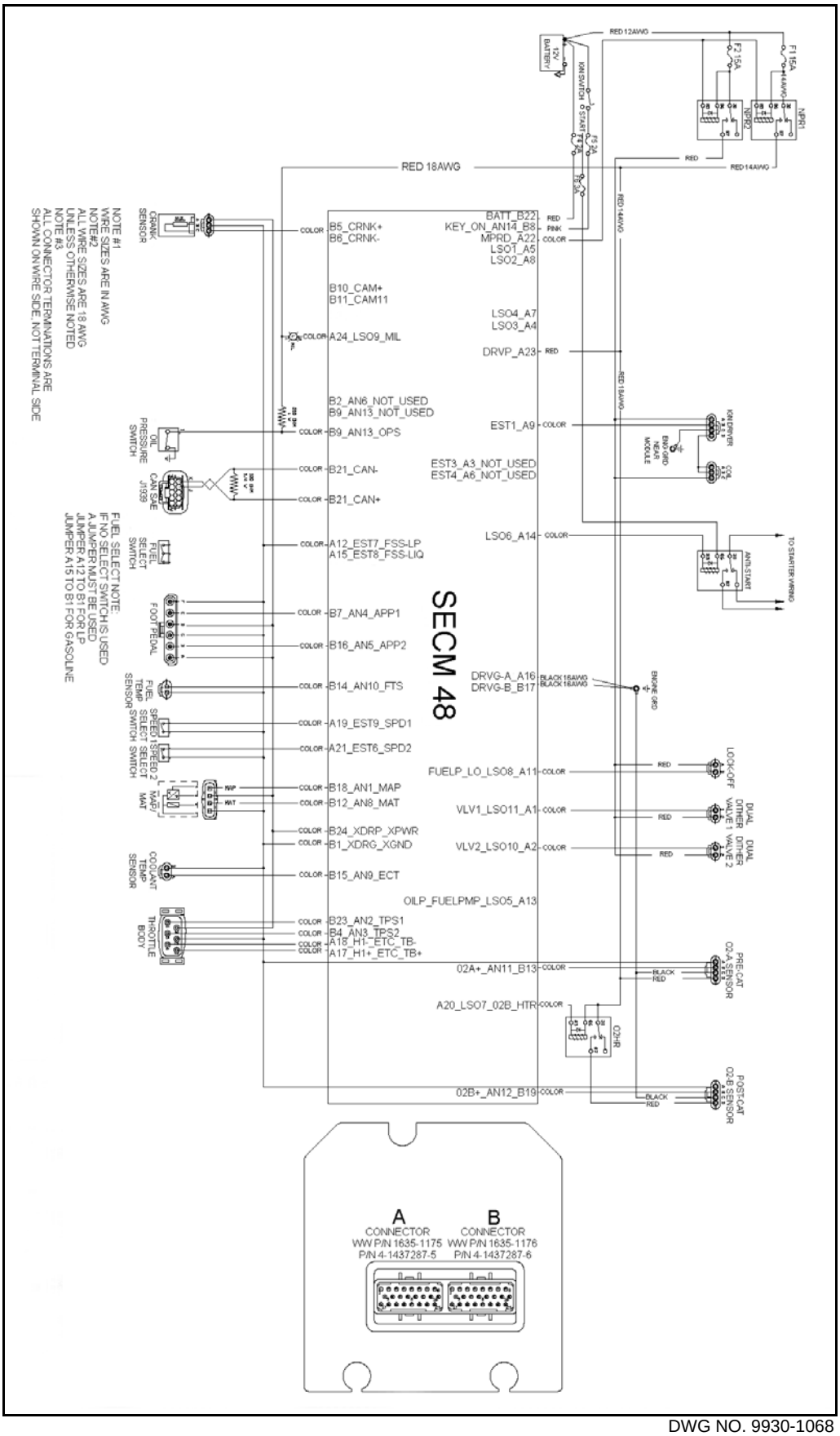

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Figure 22. SECM Wiring Diagram for LP System

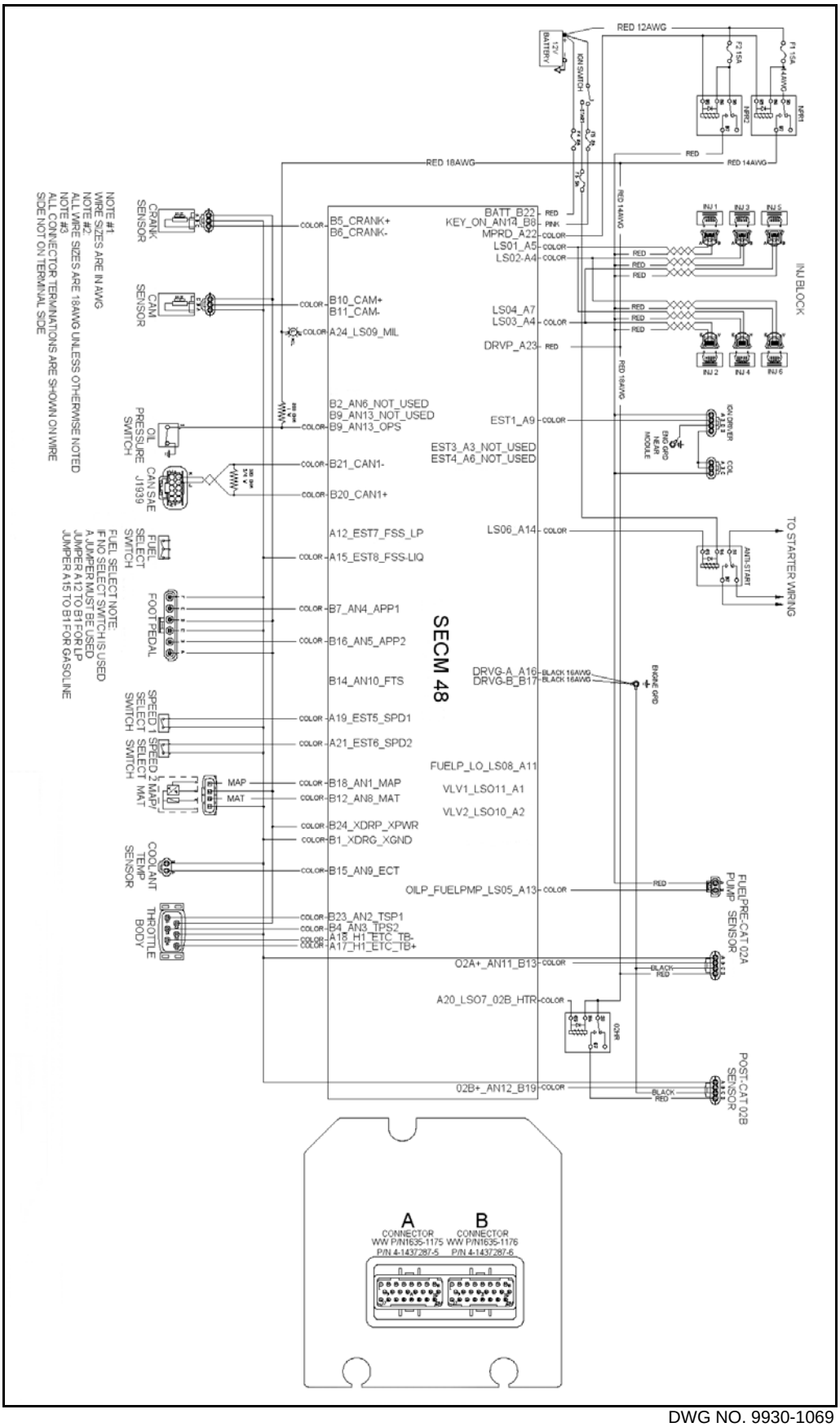

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Figure 23. SECM Wiring Diagram for Gasoline System

Chapter 2.
Gasoline Engines

Gasoline Fuel System

A gasoline fuel system includes the following components:

Gasoline fuel pump*

Fuel filter*

Fuel rail*

Pressure regulator*

Fuel injectors*

Small engine control module (SECM)
and related sensors and equipment

(*) Supplied by customer

Multi-Point Injection (MPI) is supplied with this system. However, the SECM lacks sufficient channels to drive each injector individually therefore the injectors are driven in batches of two (1 and 4, 2 and 5, 3 and 6). Fuel injection pressure and flow rate depend on engine-specific fuel injection requirements. A variety of regulators and injectors can be used to fit individual needs. The gasoline fuel pressure regulator is a one-way, non-return configuration. All gasoline specific components are automotive production parts and validated to strict automotive standards. Four (4) injection channels are supported by the SECM but only three are used in this application.

Use of unleaded gasoline of 87 octane or higher is recommended for optimal performance of the MI-07 system.

Gasoline Fuel System Specifications

Fuel	87 octane $(R+M)/_2$ method automotive grade fuel
Fuel System	One-way returnless
Fuel Pump	Minimum of 200 ml/min at rated pressure
Fuel Pressure Regulator	3 bar
Injectors	Bosch High Impedance (OEM installed)

Chapter 3.
Specifications

LP Fuel System Requirements

Operating Temperature	-20 °F to 221°F [-29 °C to 105 °C]
Long-term Storage Temperature	-40 °F to 140 °F [-40 °C to 60 °C]
Short-term Storage Temperature (Heat Soak)	≤ 257 °F [125 °C]
LPG Composition Requirements	HD5 / HD10 LPG. Failure to use fuel compliant with HD5 or HD10 standards will void the user warranty.
Fuel Filter Micron Size	10 micron or better at 99% efficiency

Environmental / Electrical Specifications

Ambient Operating Temperature	-20 °F to 221°F [-29 °C to 105 °C]
LPG Fuel Temperature	-20 °F to 120 °F [-29 °C to 49 °C] (Due to the low vapor pressure of LPG below -20 °F (-29 °C), repeated cranking to start the engine may be required
Operating Voltage	8-16 Vdc
Over Voltage Operation	18 Vdc for less than 5 minutes 24 Vdc for less than 1 minute

N-2007 Pressure Regulator Specifications

Fuel Supply Pressure	10 psi to 250 psi (68.95 kPa to 1723.69 kPa)
Fuel Inlet Fitting	1/4” NPT
Fuel Outlet Fitting	One 3/4” NPT plug. One 3/4" NPT to 5/8” hose fitting.
Fuel Supply Temperature at Tank Outlet	-20 °F to 120 °F [-29 °C to 49 °C]
Primary Pressure Tap	1/8” NPT with plug
Max Flow	50 lbm/hr LPG
Coolant Flow to Vaporizer	> 1.0 gpm/100bhp, equipped with 140 °F (60 °C) thermostat
Fuel Outlet Pressure Setpoints	-0.7 ± 0.2 inH_2O @ 1.7 lbm/hr LPG (-1.744 ± 0.498 mbar) @ 1.7 lbm/hr LPG) -2.0 ± 0.2 inH_2O @ 50 lbm/hr LPG (-4.982 ± 0.498 mbar) @ 50 lbm/hr LPG)
Mounting	Regulator should be installed with centerline of outlet at least 15° below horizontal to permit drainage of any liquid precipitates from LPG fuel. Diaphragm should be vertically oriented.

CA100 Mixer Specifications

Fuel	LPG
Fuel Inlet Fitting	5/8” hose to 1/2” NPT fitting. Fuel inlet fitted with Delphi temperature sensor
Air Intake Flange	2.25” (57.15mm) ID inlet, four #10-24 screws in 1.94” (49.28mm) square pattern
Mixer Mounting Flange	1.87” (47.49mm ID outlet, four #12-24 screws arranged in a rectangular pattern
Reference Pressure Ports	Two 1/8” NPT ports. Pressure readings must be identical within 0.25 inH_2O (0.623 mbar) at all airflows.
Air Valve Vacuum (AVV) Port Size	1/4-28 UNF
Fuel Inlet Adjustments	None
Idle Air Adjustment	None
Mounting	Suitable for on-engine mounting in vertical orientation

Electronic Throttle System Specifications

Minimum Electrical Resistance of Throttle Actuator	1.5 ohms

SECM Specifications

Operating Temperature	-20 °F to 221°F [-29 °C to 105 °C]
Long-term Storage Temperature	-40 °F to 140 °F [-40 °C to 60 °C]
Short-term Storage Temperature (Heat Soak)	≤ 257 °F [125 °C]
Operating Voltage	8-16 Vdc SECM microprocessor may reset at voltages below 6.3 Vdc
Operating Environment	On-engine mounting, underhood automotive. Capable of withstanding spray from a pressure washer.

Fuel Trim Valve (FTV) Specifications

Actuator Type	On/off two-position valve compatible with LPG.
Operating Voltage	8-16 Vdc

Ignition System Specifications

Coil Type	Inductive
Coil Supply Voltage	8-16 Vdc
Minimum Open Circuit Voltage	> 30 kV
Minimum Coil Energy	35 mJ
Maximum Dwell Time	4 msec
Operating Temperature	-20 °F to 221°F [-29 °C to 105 °C]
Long-term Storage Temperature	-40 °F to 140 °F [-40 °C to 60 °C]
Short-term Storage Temperature (Heat Soak)	≤ 257 °F [125 °C]

System Control Performance Specifications

Power /Torque

The MI-07 system maximizes engine power and torque while meeting customer-specific needs for emissions, fuel consumption, durability, and drivability. Bear in mind that engine power is dependent on many variables other than the fuel control system, i.e., compression ratio, friction, valve timing, etc.

Exhaust Emissions

MI-07 is capable of meeting EPA 2007 LSI engine emission standards when operating properly with an approved three-way catalyst. Emission standards must be met on both the LSI engine off-highway transient emissions test cycle and the ISO 8178 type C2 steady-state emissions test cycle.

The fuel control logic, for both LPG and gasoline, employs a closed-loop exhaust gas oxygen control algorithm in order to compensate for fuel system tolerances, aging, altitude, and fuel composition. The algorithm utilizes dual heated exhaust gas oxygen (HEGO) sensors with an output that switches high and low at stoichiometry. When operated with LPG, the control logic compensates for variations in fuel temperature as measured at the mixer inlet.

Drivability / Transient Response

The engine will meet requirements of the EPA LSI engine transient emissions test cycle. It should start, run, accelerate, decelerate, and stop without hesitation or miss-fire.

Low Idle Speed

The low idle speed setpoint ranges between 500 RPM and 800 RPM, as defined by the OEM during calibration.

Maximum Speed / High Idle

The maximum governed speed setpoint ranges between 1800 RPM and 3000 RPM, as defined by the OEM during calibration.

Chapter 4.
Recommended Maintenance

Suggested maintenance requirements for an engine equipped with an MI-07 fuel system are contained in this section. The operator should, however, develop a customized maintenance schedule using the requirements listed in this section and any other requirements listed by the engine manufacturer.

Maintenance Tests & Inspections

Test Fuel System for Leaks

- Obtain a leak check squirt bottle or pump spray bottle.
- Fill the bottle with an approved leak check solution.
- Spray a generous amount of the solution on the fuel system fuel lines and connections, starting at the storage container.
- Wait approximately 15-60 seconds, then perform a visual inspection of the fuel system. Leaks will cause the solution to bubble.
- Listen for leaks.
- Smell for LPG odor which may indicate a leak.

- Repair any leaks before continuing.
- Crank the engine through several revolutions. This will energize the fuel lock-off and allow fuel to flow to the pressure regulator/converter. Apply additional leak check solution to the regulator/ converter fuel connections and housing. Repeat leak inspection as listed above.
- Repair any fuel leaks before continuing.

Inspect Engine for Fluid Leaks

- Start the engine and allow it to reach operating temperatures.
- Turn the engine off.
- Inspect the entire engine for oil and/or coolant leaks.
- Repair as necessary before continuing.

Inspect Vacuum Lines and Fittings

- Visually inspect vacuum lines and fittings for physical damage such as brittleness, cracks and kinks. Repair/replace as required.
- Solvent or oil damage may cause vacuum lines to become soft, resulting in a collapsed line while the engine is running.
- If abnormally soft lines are detected, replace as necessary.

Inspect Electrical System

- Check for loose, dirty or damaged connectors and wires on the harness including: fuel lock-off, TMAP sensor, O_2 sensors, electronic throttle, control relays, fuel trim valves, crank position sensor, and cam position sensor.
- Repair and/or replace as necessary.

Inspect Foot Pedal Operation

- Verify foot pedal travel is smooth without sticking.

Check Coolant Level

- The items below are a general guideline for system checks. Refer to the engine manufacturer's specific recommendations for proper procedures.
- Engine must be off and cold.

WARNING—PROPER USE
Never remove the pressure cap on a hot engine.

- The coolant level should be equal to the "COLD" mark on the coolant recovery tank.
- Add approve coolant to the specified level if the system is low.

Inspect Coolant Hoses

- Visually inspect coolant hoses and clamps. Remember to check the two coolant lines that connect to the pressure regulator/converter.
- Replace any hose that shows signs of leakage, swelling, cracking, abrasion or deterioration.

Inspect Battery System

- Clean battery outer surfaces with a mixture of baking soda and water.
- Inspect battery outer surfaces for damage and replace as necessary.
- Remove battery cables and clean, repair and/or replace as necessary.

Inspect Ignition System

- Remove and inspect the spark plugs. Replace as required.
- Remove and inspect distributor cap. Check for cracks or abnormal wear on the output contacts. Replace as required.
- Remove and inspect distributor rotor. Check for abnormal wear on the rotor arm contact. Replace as required.
- Inspect the ignition coil for cracks and heat deterioration. Replace as required.

Replace Spark Plugs

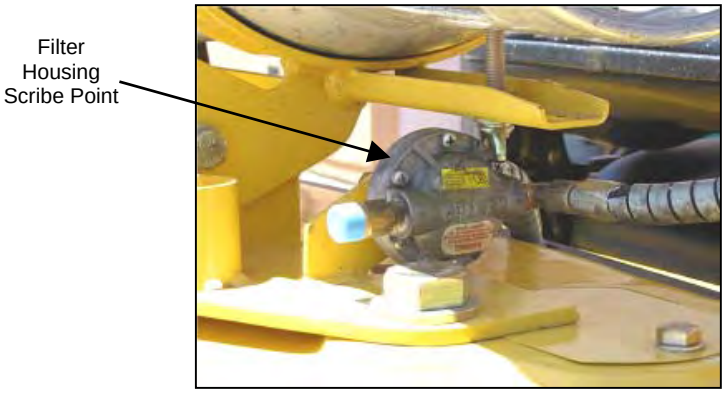
- Using a gentle twisting motion, remove the high voltage leads from the spark plugs. Replace any damaged leads.
- Remove the spark plugs.
- Gap the new spark plugs to the proper specifications.
- Apply anti-seize compound to the spark plug threads and install.
- Re-install the high voltage leads.

CAUTION
Do not over tighten the spark plugs.

Replace LP Fuel Filter Element

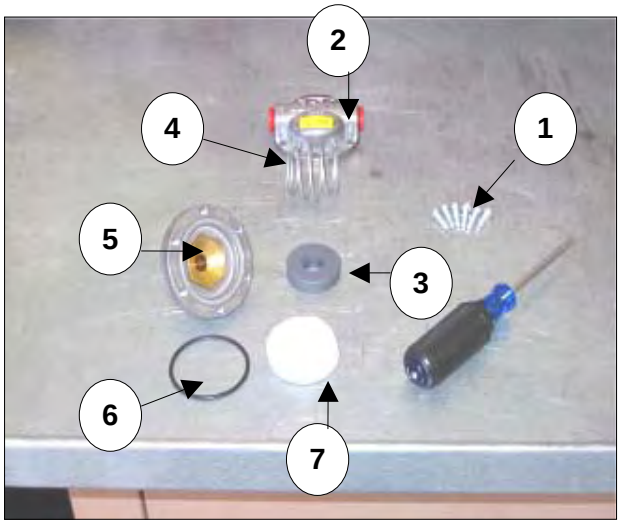
Park the lift truck in an authorized refueling area with the forks lowered, parking brake applied and the transmission in Neutral.

1. Close the fuel shutoff valve on the LP-fuel tank. Run the engine until the fuel in the system runs out and the engine stops.
2. Turn off the ignition switch.
3. Scribe a line across the filter housing covers, which will be used for alignment purposes when re-installing the filter cover.



FUEL FILTER DISASSEMBLY (Steps 4-7)

4. Remove the cover retaining screws (1).
5. Remove top cover (2), magnet (3), spring (4), and filter element (7) from bottom cover (5).
6. Replace the filter element (7).
7. Check bottom cover O-ring seal (6) for damage. Replace if necessary.
8. Re-assemble the filter assembly aligning the scribe lines on the top and bottom covers.
9. Install the cover retaining screws, tightening the screws in an opposite sequence across the cover.
10. Open the fuel valve by slowly turning the valve counterclockwise.
11. Crank the engine several revolutions to open the fuel lock-off. DO NOT START THE ENGINE. Turn the ignition key switch to the off position.
12. Check the filter housing, fuel lines and fittings for leaks. Repair as necessary.



Testing Fuel Lock-off Operation

- Start engine.
- Locate the electrical connector for the fuel lock (A).
- Disconnect the electrical connector.
- The engine should run out of fuel and stop within a short period of time.

NOTE
The length of time the engine runs on trapped fuel vapor increases with any increase in distance between the fuel lock-off and the pressure regulator/converter.

- Turn the ignition key switch off and re-connect the fuel lock-off connector.

Figure 24. MI-07 System Installed on GM 3.0L Engine

Pressure Regulator/Converter Inspection

- Visually inspect the pressure regulator/converter (B) housing for coolant leaks.
- Refer to Chapter 5 if the pressure regulator/converter requires replacement.

Fuel Trim Valve Inspection (FTV)

- Visually inspect the fuel trim valves (C) for abrasions or cracking. Replace as necessary.
- To ensure a valve is not leaking a blow-by test can be performed.
  1. With the engine off, disconnect the electrical connector to the FTVs.
  2. Disconnect the vacuum line from the FTVs to the pressure regulator/converter at the converter's tee connection.
  3. Lightly blow through the vacuum line connected to the FTVs.
     Air should not pass through the FTVs when de-energized.
     If air leaks past the FTVs when de-energized, replace the FTVs.

Inspect Air/Fuel Valve Mixer Assembly

- Refer to Chapter 5 for procedures regarding the LP mixer (D).

Inspect for Intake Leaks

- Visually inspect the intake throttle assembly (E), and intake manifold for looseness and leaks. Repair as necessary.

Inspect Throttle Assembly

- Visually inspect the throttle assembly motor housing for coking, cracks, and missing cover-retaining clips. Repair and/or replace as necessary.

NOTE
Refer to Chapter 5 for procedures on removing the mixer and inspecting the throttle plate.

Checking the TMAP Sensor

- Verify that the TMAP sensor (F) is mounted tightly into the manifold or manifold adapter (E), with no leakage.
- If the TMAP is found to be loose, remove the TMAP retaining screw and the TMAP sensor from the manifold adapter.
- Visually inspect the TMAP O-ring seal for damage. Replace as necessary.
- Apply a thin coat of an approved silicon lubricant to the TMAP O-ring seal.
- Re-install the TMAP sensor into the manifold or manifold adapter and securely tighten the retaining screw.

Inspect Engine for Exhaust Leaks

- Start the engine and allow it to reach operating temperatures.
- Perform visual inspection of exhaust system from the engine all the way to the tailpipe. Any leaks, even after the post-catalyst oxygen sensor, can cause the sensor output to be effected (due to exhaust pulsation entraining air upstream). Repair any/all leaks found. Ensure the length from the post-catalyst sensor to tailpipe is the same as original factory.
- Ensure that wire routing for the oxygen sensors is still keeping wires away from the exhaust system. Visually inspect the oxygen sensors to detect any damage.

Maintenance Schedule

NOTE

The MI-07 fuel system was designed for use with LPG fuel that complies with HD5 or HD10 LPG fuel standards. Use of non-compliant LPG fuel may require more frequent service intervals and will disqualify the user from warranty claims.

CHECK POINT	INTERVAL HOURS					
	Daily	Every 250 Hours or 1 month	Every 500 Hours or 3 months	Every 1000 Hours or 6 months	Every 1500 Hours or 9 months	Every 2500 Hours or 1 year
General Maintenance						
Test fuel system for leaks.	Prior to any service or maintenance activity					
Inspect engine for fluid leaks.	X					
Inspect all vacuum lines and fittings.			X			
Inspect electrical system; check for loose, dirty, or damaged wires and connections.			X			
Inspect isolation mounts on engine control module for cracks and wear; replace as necessary.			X			
Inspect all fuel fittings and hoses.				X		
Inspect foot pedal travel and operation.	X					
Replace timing belt						X
Check for MIL lamp test at key-on. If MIL lamp remains illuminated (indicating a fault), use pedal to recover fault code(s). Repair faults.	X					
Engine Coolant						
Check coolant level.	X					
Inspect coolant hoses and fittings for leaks, cracks, swelling, or deterioration.				X		
Engine Ignition						
Inspect battery for damage and corroded cables.						X
Inspect ignition system.					X	
Replace spark plugs					X	
Fuel Lock-Off/Filter						
Replace LP fuel filter element.				X		
Inspect lock-off and fuel filter for leaks.				X		
Ensure lock-off stops fuel flow when engine is off.				X		

CHECK POINT	INTERVAL HOURS					
	Daily	Every 250 Hours or 1	Every 500 Hours or	Every 1000 Hours or	Every 1500 Hours or	Every 2500 Hours or
Pressure Regulator/Converter						
Test regulator pressures.				X		
Inspect pressure regulator vapor hose for deposit build-up. Clean or replace as necessary.				X		
Inspect regulator assembly for fuel/coolant leaks.				X		
Fuel Trim Valve						
Inspect valve housing for wear, cracks or deterioration.				X		
Ensure valve seals in the closed position when the engine is off.				X		
Replace FTV.	When indicated by MIL					
Carburetor						
Check air filter indicator.	X					
Check for air leaks in the filter system.				X		
Inspect air/fuel valve mixer assembly for cracks, loose hoses, and fittings. Repair or replace as necessary.			X			
Check for vacuum leaks in the intake system including manifold adapter and mixer to throttle adapter.						X
Repair or replace throttle assembly.	When indicated by MIL					
Inspect air filter.			X			
Replace air filter element.				X		
Check TMAP sensor for tightness and leaks.						X
Exhaust & Emission						
Inspect engine for exhaust leaks.	X					
Replace PCV valve and breather element.						X
Replace HEGO sensors	When indicated by MIL					
Gasoline Engines						
Replace gasoline fuel filter element.				X		
Inspect gasoline fuel system for leaks.				X		
Confirm gasoline supply pressure is correct.	Pressure should be 45-55 psig (310.26-379.21 kPa)					

Chapter 5.
Installation Procedures

WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area.**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/converter or mixer.

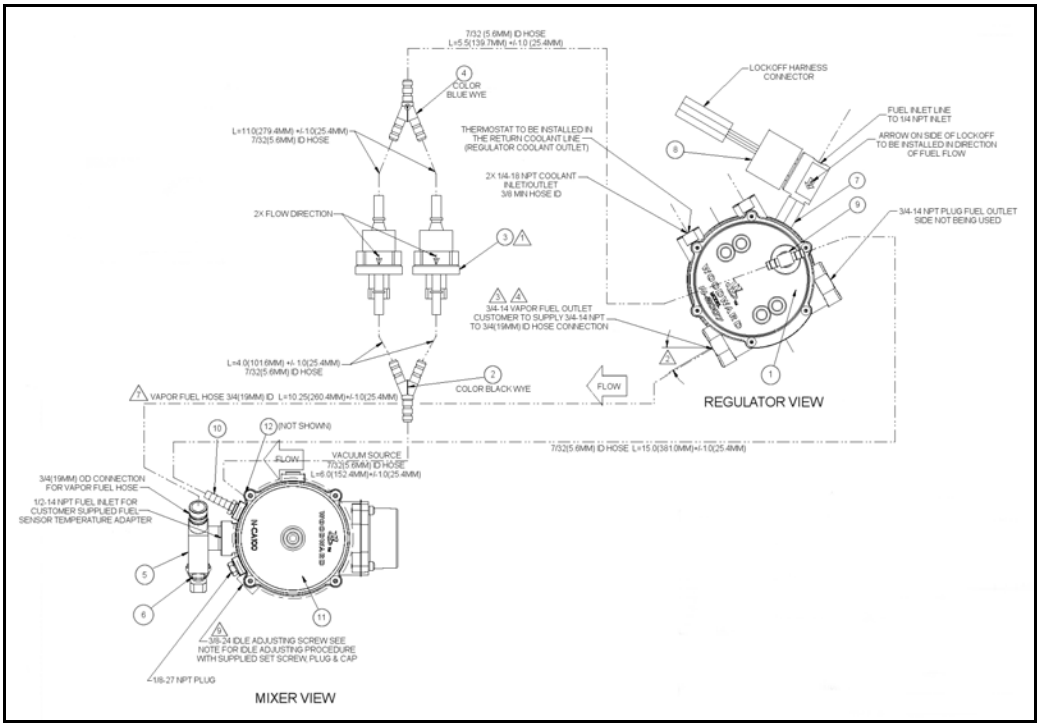
Hose Connections

Proper operation of the closed loop control greatly depends on the correct vacuum hose routing and fuel line lengths. Refer to the connection diagram below for proper routing and maximum hose lengths when reinstalling system components.

NOTE: Preferred mounting of regulator is off engine.

Hose Specifications

Vacuum hose to comply to SAE 1403 Type L or SAE J30 R7 R8 / EPDM textile reinforced / -40° F to +257° F (-40° C +125° C / Inside Diameter: 7/32" (5.56mm)


REGULATOR VIEW
MIXER VIEW
LOCKOFF HARNESS CONNECTOR
FUEL INLET LINE TO 1/4 NPT INLET
ARROW ON SIDE OF LOCKOFF TO BE INSTALLED IN DIRECTION OF FUEL FLOW
THERMOSTAT TO BE INSTALLED IN THE RETURN COOLANT LINE (REGULATOR COOLANT OUTLET)
2X 1/4-18 NPT COOLANT INLET/OUTLET 3/8 MIN HOSE ID
2X FLOW DIRECTION
3/4-14 NPT PLUG FUEL OUTLET SIDE NOT BEING USED
3/4-14 VAPOR FUEL OUTLET CUSTOMER TO SUPPLY 3/4-14 NPT TO 3/4(19MM) ID HOSE CONNECTION
COLOR BLUE WYE
COLOR BLACK WYE
FLOW
VACUUM SOURCE
3/4(19MM) OD CONNECTION FOR VAPOR FUEL HOSE
1/2-14 NPT FUEL INLET FOR CUSTOMER SUPPLIED FUEL SENSOR TEMPERATURE ADAPTER
1/8-27 NPT PLUG

DWG NO 5555-1206

Figure 25. Hose Connections for 3.0L Engines

DIAGRAM NOTES

△1 Trim valves must be positioned vertically with flow in direction shown

△2 Fuel outlet must be min 15° below horizontal position

△3 Only one 90° fitting permissible on vapor fuel line between mixer and regulator (As shown the temp sensor adaptor is considered the one 90° fitting.)

△4 Vapor fuel fittings (regulator and mixer) must have minimum ID of 0.59" (15mm)

△7 Vapor hose length to be as short as possible and have no restrictions for best regulator performance

△9 Setting Idle Adjustment:
1. Set idle adjustment to correct setting.
2. Lock with supplied set screw.
3. Cap after adjustment and locking screw.

(1) N-2007 Regulator

(2) Plastic WYE Fitting (black color) for 1/4" (6.35mm) ID Tube Hose

(3) Valve (TEV Bosch Canister)

(4) Plastic WYE Fitting (blue color) for 1/4" (6.35mm) ID Tube Hose

(5) Adapter (temperature sensor)

(6) Sensor (coolant, temperature)

(7) Nipple (.625 hex 4mp, 2.5L steel)

(8) Solenoid (AFS Lock Off Valve)

(9) Brass Tee Fitting. 1/4 Tube x 1/8 NPTF x 1/4 Tube

(10) 1/4" (6.35mm) hose barb to 1/8" (3.2mm) male pipe, 125HBL, .062 flow ID

(11) CA100 Mixer

(12) 1/4-28 UNF x 1/4" (6.35mm) hose barb

Removal and Installation of N-2007 LP Regulator/Converter

Follow the procedures below for removal and reinstallation of the N-2007 regulator in certified systems.

N-2007 Removal Steps

Refer to **Figure 28.**

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.
2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.
3. Key switch in “OFF” position.
4. Remove the fuel inlet line (**1**) from the lock-off, the two vacuum lines (**2**) from the branch-tee fitting in the regulator vent and disconnect the lock-off connector (**3**).
5. Remove the four rear-mounting bolts that hold the regulator to the support bracket. This will allow easier access to the remaining hose clamps.
6. Remove the two cooling lines (**4**) from the regulator. *NOTE: Either drain the coolant system or clamp off the coolant lines as close to the regulator as possible to avoid a coolant spill when these lines are disconnected.*
7. Remove the fuel vapor outlet hose (**5**) from the regulator.
8. Remove the nipple extension (**6**) with the lock-off from the regulator.

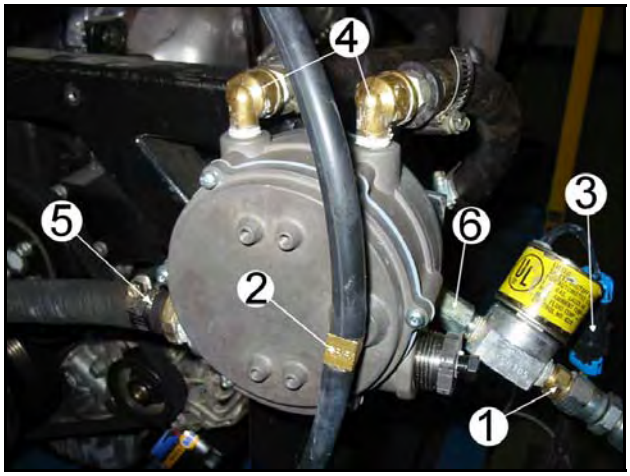


Figure 26. N-2007 Regulator Installed on Engine

N-2007 Installation Steps

Refer to **Figure 26.**

1. Install the nipple extension (**6**) with the lock-off to the regulator.
2. Install the fuel vapor outlet hose (**5**) to the regulator.
3. Install the two cooling lines (**4**) to the regulator.
4. Install the four rear-mounting bolts that hold the regulator to the support bracket. Use a torque wrench and tighten each bolt to 60-70 lbf-in (6.78-7.91 N-m).
5. Install the fuel inlet line (**1**) to the lock-off, the two vacuum lines (**2**) to the branch-tee fitting in the regulator vent and re-connect the lock-off connector (**3**).
6. Open the liquid outlet valve in the forklift cylinder or fuel storage container.

Removal and Installation of CA100 Mixer

Follow the procedures below for removal and reinstallation of the CA100 mixer in certified systems.

CA100 Certified Mixer Removal Steps

Refer to **Figure 27**.

1. Close the liquid outlet valve in the forklift cylinder or fuel storage container.
2. Purge the system of fuel by starting the engine and running until all trapped fuel in the system is exhausted and the engine shuts down.
3. Key switch in “OFF” position.
4. Remove the air cleaner hose (**1**).
5. Mark the two vacuum lines (**2**) to the mixer for identification, as they must be reinstalled correctly for proper operation. Remove the two vacuum lines.
6. Remove vapor fuel inlet line (**3**) from the fuel temperature sensor fitting (**4**).
7. Disconnect the fuel temperature sensor connector (**5**).
8. Disconnect the wires leading to the electronic throttle body by pinching the lock tabs on either side of the wiring harness connector. (See **Figure 28** for location of connector.)
9. Loosen the four bolts (**6**) that secure the mixer/adapter/throttle body assembly to the intake manifold.
10. Remove the mixer (**9**), the adapter (**7**), and the throttle body (**8**) as an assembly by gently pulling upwards. Take care not to drop anything down the intake manifold.
11. Gently wiggle and pull to separate mixer and adapter from the throttle body. Take note of the adapter orientation on the mixer, as it must be reinstalled correctly for proper fit on the throttle.
12. Remove the four mounting screws that attach the throttle body adapter to the mixer.
13. Remove the fuel temperature sensor (not shown) from the tee (**4**).
14. Remove the fuel temperature sensor fitting from the mixer. Take note of the fitting’s orientation on the mixer, as it must be reinstalled correctly for proper fit.
15. Remove the short vacuum port barb from the mixer. (See **Figure 29** for location of port barb on mixer.)

New photo to COME

Figure 27. CA100 Mixer Installed on Engine

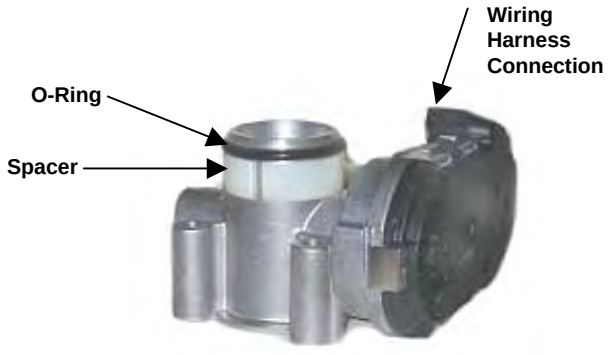


Figure 28. O-Ring and Spacer Within Mixer Adapter Assembly

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Figure 29. Throttle Adapter Mount Screws & Vacuum Port Barbs

CA100 Mixer Installation Steps

Refer to **Figure 27**.

1. Install the vacuum port barb onto the mixer (**9**).
2. Install the fuel temperature sensor fitting (**4**) onto the mixer.
3. Install the fuel temperature sensor into the fitting.
4. Install the four mounting screws that attach the throttle adapter (**7**) to the mixer. See **Figure 29**.
5. Position the mixer/adapter assembly onto the throttle body (**8**), then drop in the four mounting bolts (**6**) and gently push down on the assembly until it rests on the throttle body. Be careful not to pinch the O-ring.
   (See **Figure 28**.)
6. Attach the mixer/throttle body assembly to the intake manifold, making sure gasket is in place. Tighten the four mounting bolts.
7. Connect the wiring harness to the throttle body. (See **Figure 28** for location of connector.) Connect the fuel temperature sensor connector (**5**) to the sensor.
8. Install the vapor fuel inlet line (**3**) to the fuel temperature sensor fitting.
9. Install the two vacuum lines (**2**) to the mixer using the previous marks for identification. Vacuum lines must be installed correctly for proper operation.
10. Install the air cleaner hose (**1**).

Chapter 6.
Tests and Adjustments

WARNING—PROPER USE

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**
- **Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.**

CAUTION

The regulator/converter and mixer are part of a certified system complying with EPA and CARB 2007 requirements. Only trained, certified technicians should perform disassembly, service or replacement of the regulator/converter or mixer.

N-2007 Regulator Service Testing

For checking the N-2007 regulator/converter operation, the following tests can be performed (See Chapter 5 for removal/installation of the N-2007 regulator). To check the secondary regulation (output) a simple vacuum hand pump can be used to simulate the vacuum signal transmitted from the air/fuel mixer when the engine is running. See listing below for required hardware.

Break-Off Test

Secondary Stage Test Hardware

1. Hand vacuum pump
2. Regulator vapor outlet test fitting 3/4” NPT x 1/4” hose barb
3. Union Tee 1/4” NPT with three 1/4” NPT x 1/4” hose barb
4. Vacuum hose
5. 0-3” WC Magnehelic gauge (inches of water column)

Secondary Stage (Break-Off) Test

1. Connect the vacuum pump, the Magnehelic gauge, and the regulator vapor outlet to the Union Tee fitting (**Figure 30**). Make sure there is no leakage at any of the fittings.
2. Using the vacuum pump slowly apply enough vacuum to measure above -2” WC on the gauge. This vacuum signal opens the secondary valve in the N-2007 regulator/converter.
3. Release the vacuum pump lever and you will see the gauge needle start falling back toward zero. When the pressure drops just below the specified break-off pressure (-0.5 +/- 0.35 “ WC) of the secondary spring, the needle should stop moving.

4. At this point the secondary valve should close. If the secondary valve seat or the secondary diaphragm is leaking the gauge needle will continue to fall toward zero (proportional to the leak size). An excessively rich air/fuel mixture can be caused by a secondary valve seat leak and the regulator should be replaced.

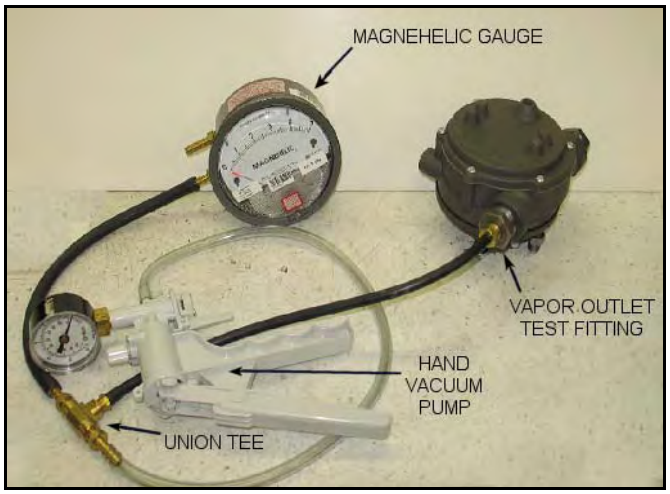


Figure 30. Secondary Stage Test Connection

Pressure Test

Primary Stage Test Hardware

1. Shop air pressure regulator adjusted to 100 psi
2. Shop air hose fitting (1/4” NPT to air hose)
3. Air hose
4. Test gauge fitting (1/16” NPT x 1/4” hose barb)
5. Vacuum hose or vinyl tubing
6. 0-60” WC Magnehelic gauge (inches of water column)

Primary Stage Pressure Test

1. Remove the primary test port plug from the side of the regulator and install the 1/16” NPT hose barb fitting (**Figure 31)**.
2. Connect a compressed air line (shop air ~100 psi) to the liquid propane fuel inlet of the N-2007 regulator (**Figure 31)**.

Figure 31. Primary Stage Test Connection

3. Apply compressed air, wait for air to exit the hose barb in the test port, and then connect the Magnehelic gauge (**Figure 32**) to the hose barb using the vacuum hose or vinyl tubing. This prevents the gauge from reading maximum pressure due to the large velocity of compressed air entering the primary chamber.
4. Make sure there is no leakage at any of the fittings. The static pressure should read between 40-60" of water column on the Magnehelic gauge and maintain a constant pressure for 60 seconds.

Figure 32. Magnehelic Gauge Connection to Hose Barb

5. If the pressure reading begins to **increase**, a leak is most likely present at the primary valve, either the primary valve o-ring or the valve itself. If a leak is present the regulator is defective.
6. If the pressure begins to **decrease**, the secondary seat is probably not making an adequate seal and is leaking. The regulator is defective.
7. If the test is successful, re-install the primary test port plug and check the fittings for leaks. See Chapter 5 for installation of the N-2007 regulator.

NOTE

The N-2007 primary stage pressure can also be tested at idle on a running engine. The N-2007 primary pressure should be between 40 inH20 (99.635 mbar) and 55 inH20 (136.999 mbar) at 750 RPM, idle.

WARNING

- **LP gas is highly flammable. To prevent personal injury, keep fire and flammable materials away from the lift truck when work is done on the fuel system.**
- **Gas vapor may reduce oxygen available for breathing, cause headache, nausea, dizziness and unconsciousness and lead to injury or death. Always operate the forklift in a well ventilated area**

Liquid propane may cause freezing of tissue or frostbite. Avoid direct contact with skin or tissue; always wear appropriate safety protection including gloves and safety glasses when working with liquid propane.

AVV (Air Valve Vacuum) Testing

Purpose of Test

Check for excessive or inadequate pressure drop across CA100 mixer.

AVV Test Hardware

1. Union Tee fitting, 1/4” (6.35mm) NPT
   with three 1/4” (6.35mm) NPT x 1/4” (6.35mm) hose barbs.
2. Vacuum hose.
3. 0-20” H_2O differential pressure Magnehelic gauge.

AVV Test

1. Install Union Tee fitting in the hose between the FTVs and the AVV fitting. Connect this fitting to the low pressure port of the Magnehelic gauge (**Figure 33)**.
2. Leave high pressure port of the Magnehelic gauge exposed to ambient pressure (**Figure 33**).
3. With the engine fully warmed up and running at idle (750 RPM) place the transmission in Neutral. The AVV should be between 5” and 8” H_2O of pressure vacuum.
4. If the measured pressure drop is excessively high, check for sticking or binding of the diaphragm air valve assembly inside the mixer. Replace mixer if necessary.
5. If the measured pressure drop is low, check for vacuum leaks in the manifold, throttle, mixer, TMAP sensor and attached hoses.

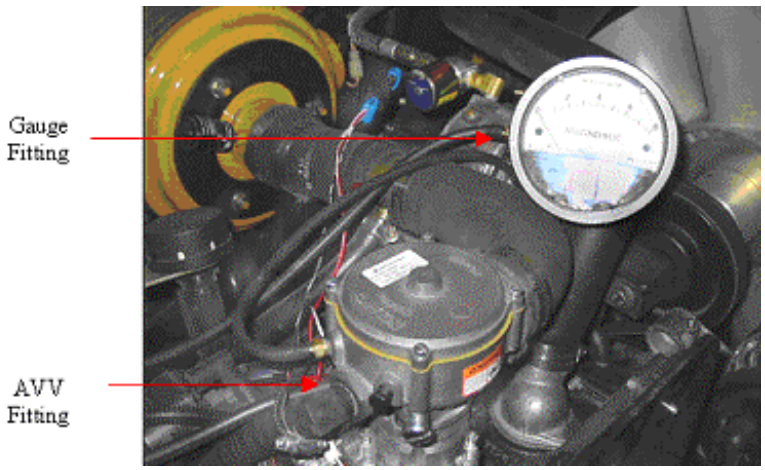


Figure 33. Magnehelic Gauge Connection

Ignition Timing Adjustment

With the MI-07 system, ignition-timing advance is controlled by the SECM.

The initial ignition timing needs to be set by the MOR. This setup requires a specific technique for each engine installation.

Connection of MI-07 Service Tool

To use the Service Tool, a Universal Serial Bus (USB) to Controller Area Network (CAN) communication adapter by KVaser will be required along with a Crypt Token (**Figure 34**). The Crypt Token acts as a security key allowing the laptop to retrieve the necessary data from the SECM.

1. Install the Crypt Token in an available USB port in the computer (**Figure 35**).
2. With the ignition key in the OFF position, connect the KVaser communication cable from a second USB port on the computer to the CAN communications cable on the engine. *(*If your laptop computer does not have a second USB port an appropriate USB hub will need to be used).*
3. Connect a timing light to the engine.
4. Turn the ignition key to the ON position ***(Do Not Start the Engine)***.
5. Launch the MotoView program on your computer and open the Service Tool display (**Figure 36**).

Figure 34. KVaser Communication Adapter

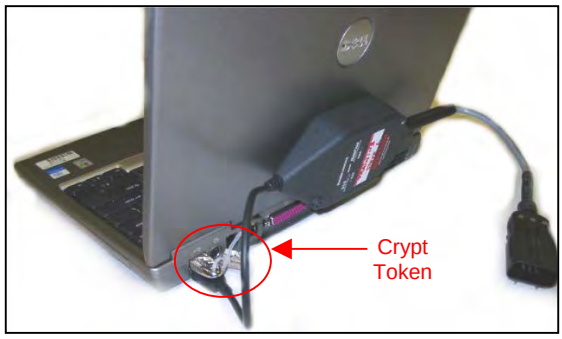


Figure 35. Crypt Token Installed on Laptop

Figure 36. Opening the Service Tool Display

Idle Mixture Adjustment

NOTE
Be sure engine is fully warm (ECT>180°F [82°C]) before performing the idle mixture adjustment.

The CA100 mixer requires adjustment of the idle mixture screw to assure optimal emissions and performance. This adjustment accounts for minor part-to-part variations in the fuel system and assures stable performance of the engine at idle. Once adjusted, the idle mixture screw is sealed with a tamper proof cap, after which it need not be adjusted for the life of the vehicle.

Therefore, the only situations in which the idle mixture screw needs to be adjusted are when the engine is initially fitted with a fuel system at the factory and following the field replacement of the mixer. Under these situations, follow the procedures below for adjustment of the idle mixture screw.

Factory Test Preparation:

1. Install the MI-07 fuel system, wiring harness and SECM-48 control module on the engine.
2. All coolant hoses should be attached, filled with coolant and bled to remove any air.
3. Attach LPG fuel lines.
4. Attach wiring harness to battery power.
5. Attach exhaust system.
6. If present, set fuel select switch to LPG fuel.

When operated at the factory, it is critical to simulate the airflow found on a forklift at idle as nearly as possible in order to achieve the proper air valve lift in the mixer. It may be necessary to place a load on the engine to achieve the required airflow without overspeeding the engine. Means of achieving this load include:

a) Place an electrical load on the alternator. The alternator should be able to briefly hold loads of approximately 1.2 kW.
b) Attach the engine to a dynamometer.

Factory Adjustment Procedure:

> **NOTE**
> **Be sure engine is fully warm (ECT>180°F [82°C]) before performing the idle mixture adjustment.**

1. Operating the engine on LPG fuel, start the engine and permit the engine to warm up until the coolant temperature (ECT on Mototune display) is approximately 180°F (82 °C).
2. Set APP input to minimum.
3. Adjust the load until engine speed reaches 750 RPM.
4. Mototune display parameter LP Fuel Control must display “Closed Loop.”
5. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.
6. To adjust the idle mixture screw, use a 3/16” hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counter-clockwise) should decrease the duty cycle.
7. Adjust the idle mixture screw on the mixer until a reading of **40-47%** is reached for the FTV Duty Cycle in Closed Loop Idle (**Figure 37**).

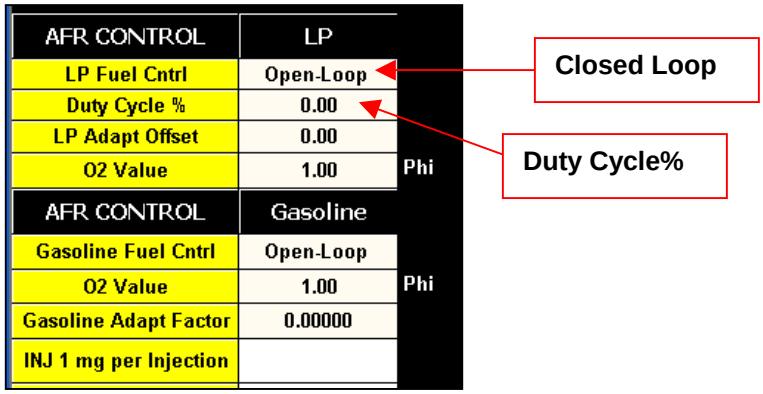


Figure 37. FTV Duty Cycle Percentage Displayed on Service Tool

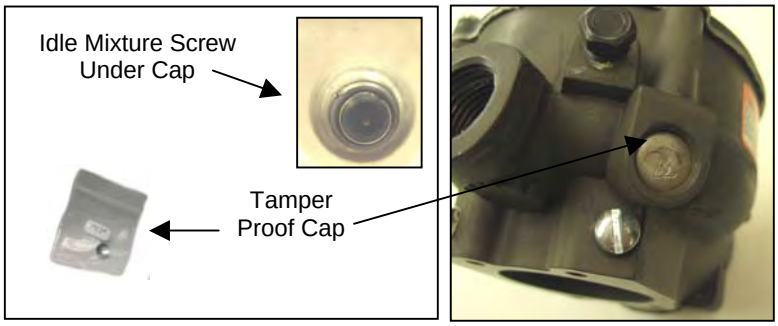
8. Use the accelerator pedal to increase RPM above idle momentarily (*rev the engine*) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (**40-47%**).
9. Use the Mototune Service Tool to lock the FTV duty cycle. Set display parameter DitherValveDC_ovr = locked (displayed in screen tab Manual Override 1 under AFR Trim Vales, select “locked” under box labeled Lock DC%).
10. Use the Mototune Service Tool to monitor throttle position (TPS_1) and Exhaust gas oxygen equivalence ratio (“O_2 Value” in Figure 1). While monitoring O_2, slowly increase the pedal input (APP) to achieve a TPS_1 value of 15%.
11. Use the Mototune Service Tool to unlock the FTV duty cycle. Set display parameter DitherValveDC_ovr = unlocked (displayed in screen tab Manual Override 1 under AFR Trim Vales, select “unlocked” under box labeled Lock DC%).
12. If at any time in step 10, O_2 was greater than 1.2 go to step 13. If 0_2 remained below 1.2, proceed to Step 15.

13. Adjust the idle mixture screw on the mixer until a reading of **50-55%** is reached for the FTV Duty Cycle in Closed Loop Idle (**Figure 37**).
14. Use the accelerator pedal to increase RPM above idle momentarily (*rev the engine*) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (**50-55%**).

NOTE
If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.

15. Turn the ignition key to the **OFF** position to shut down the engine.
16. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (**Figure 38)**.

Figure 38. Installing Tamper Proof Cap



Field Adjustment Procedure:

The idle mixture adjustment should only be necessary on a new mixer that does not have the tamper proof cap installed. The method for making the idle mixture adjustment to a running engine is to use the Service Tool software by connecting a laptop computer to the SECM. If you do not have the Service Tool, a multimeter capable of measuring duty cycle, such as a Fluke 87 III, can be used. If using a multimeter, connect the meter positive lead to the battery positive wire and the meter negative to the FTV signal wire. For the Fluke 87, press the "RANGE" button until 4 or 40 appears in the lower right-hand corner of the display. Press the "Hz" button twice so that the percent sign (%) appears on the right-hand side of the display. The multimeter will then read the duty cycle percentage the just like the Service Tool shown in **Figure 37**.

1. After installing a new mixer, operate the engine on LPG fuel. Start the engine and permit it to warm up until the coolant temperature (ECT on Mototune display) is approximately 180°F (82 °C).
2. Place the transmission in Neutral.
3. Mototune display parameter LP Fuel Control must display "Closed Loop".
4. Use the Mototune Service Tool to monitor Duty Cycle % on the Mototune display.
5. To adjust the idle mixture screw, use a hex or Allen-type wrench. Turning the screw in (clockwise) should increase the duty cycle; turning the screw out (counterclockwise) should decrease the duty cycle.
6. Adjust the idle mixture screw on the mixer until a reading of **45-55%** is reached for the FTV Duty Cycle in Closed Loop Idle (**Figure 37)**. If engine idle performance is unstable screw the idle screw in slightly to see if stability is obtained, but in no case should duty cycle exceed 60%.
7. Use the accelerator pedal to increase RPM above idle momentarily (*rev the engine*) then release the pedal to return to idle RPM. The duty cycle setting should remain within the adjustment range (**45-55%**).
8. If the FTV duty cycle reading is above **55%** adjust the idle adjustment screw outward and re-check the duty cycle reading. Continue to do this until the FTV duty cycle reading is within the optimum range (**45-55%**). **DO NOT** adjust the screw so far outward that the tamper proof cap cannot be installed. A duty cycle measurement at Closed Loop Idle of **40-60%** is acceptable if the optimum range of **45-55%** cannot be reached through adjustment. If the FTV duty cycle cannot be adjusted below **60%**, the mixer is faulty and should be replaced.

> **NOTE**
> **If the FTV Duty Cycle reading is NOT between 25-60%, check for possible vacuum leaks, manifold leaks, or a faulty mixer.**

9. Turn the ignition key to the **OFF** position to shut down the engine.
10. Install the tamper proof cap on the idle mixture screw adjustment port using a large pin punch, so that no further adjustments can be made (**Figure 38**).

Chapter 7.
Basic Troubleshooting

Preliminary Checks

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) and are covered in Chapter 8, Advanced Diagnostics. However, items such as fuel level, plugged fuel lines, clogged fuel filters, and malfunctioning pressure regulators may not set a fault code and usually can be corrected with the basic troubleshooting steps described on the following pages.

If engine or drivability problems are encountered with your MI-07 system, perform the checks in this section before referring to Advanced Diagnostics.

NOTE: Locating a problem in a propane engine is done exactly the same as with a gasoline engine. Consider all parts of the ignition and mechanical systems as well as the fuel system.

BEFORE STARTING . . .

1. Determine that the SECM and the MIL are operating. Verify operation by keying on engine and checking for flash of the MIL.

   When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the SECM. Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

2. Determine that there are no diagnostic codes stored, or there is a diagnostic code but no MIL.

VISUAL/PHYSICALCHECK
Several of the procedures call for a “Careful Visual/Physical Check” which should include:

- SECM grounds for being clean and tight.
- Vacuum hoses for splits, kinks, and proper connection.
- Air leaks at throttle body mounting and intake manifold.
- Exhaust system leaks.
- Ignition wires for cracking, hardness, proper routing, and carbon tracking.
- Wiring for pinches and cuts.

Also check:

- Connections to determine that none are loose, cracked, or missing
- Fuel level in vehicle is sufficient
- Fuel is not leaking
- Battery voltage is greater than 11.5 volts
- Steering, brakes, and hydraulics are in proper condition and vehicle is safe to operate

NOTE
The Visual/Physical check is very important, as it can often correct a problem without further troubleshooting and save valuable time.

Basic Troubleshooting

Intermittent Faults

An intermittent fault is the most difficult to troubleshoot since the MIL flashes on at random, causing uncertainty in the number of flashes or the conditions present at the time of the fault. Also, the problem may or may not fully turn “ON” the MIL or store a code.

Therefore, the fault must be present or able to be recreated in order to locate the problem. If a fault is intermittent, use of diagnostic code charts may result in the unnecessary replacement of good components.

CORRECTIVE ACTION
Most intermittent problems are caused by faulty electrical connections or wiring. Perform careful visual/physical check for: • Poor mating of the connector halves or terminal not fully seated in the connector body (backed out). • Improperly formed or damaged terminal. All connector terminals in problem circuit should be carefully reformed or replaced to insure proper contact tension. • Loose connections or broken wires. • Poor terminal to wire connection crimp.
If a visual/physical check does not find the cause of the problem, perform the following: (1) Drive the vehicle with a voltmeter or “Service” tool connected to a suspected circuit. Check if circuit is active and signal is reasonable. (2) Using the “Service” tool, monitor the input signal to the SECM to help detect intermittent conditions. (3) An abnormal voltage, or “Service” reading, when the problem occurs, indicates the problem may be in that circuit. (4) If the wiring and connectors check OK, and a diagnostic code was stored for a circuit having a sensor, check sensor.
An intermittent “Service Engine Soon” light with no stored diagnostic code may be caused by: • Ignition coil shortage to ground and arcing at spark plug wires or plugs. • MIL wire to ECM shorted to ground. • SECM grounds (refer to SECM wiring diagrams).
Check for improper installation of electrical options such as lights, 2-way radios, accessories, etc.
EST wires should be routed away from spark plug wires, distributor wires, distributor housing, coil and generator. Wires from SECM to ignition should have a good connection.

Surges and/or Stumbles

Engine power varies under steady throttle or cruise. Surging and stumbling is characterized by the feeling that the vehicle is speeding up and slowing down with no change in the acceleration pedal.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver understands vehicle operation as explained in the operator manual.

PROBABLE CAUSE	CORRECTIVE ACTION
Oxygen sensor malfunction	The fuel management system should maintain a stoichiometric air-fuel ratio under all steady state operating conditions following engine warmup. Failure of the Pre-catalyst O_2 sensor should cause an O_2 sensor fault that can be diagnosed with the MIL or Service Tool.
Fuel system malfunction	**NOTE:** To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring pre-catalyst O_2 adapts*, dither valve duty cycle, or mechanical injector pulse width will help identify problem. Check fuel supply while condition exists. Check in-line fuel filter. Replace if dirty or plugged. Check fuel pressure.
Ignition system malfunction	Check for proper ignition voltage output using spark tester. Check spark plugs. • Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. • Repair or replace as necessary. • Check condition of spark plug wires. Check ignition timing.
Component malfunction	Check vacuum lines for kinks or leaks. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Exhaust backpressure	Check condition of exhaust system. Check backpressure before catalyst. It should be less than 3.5 psig (24.13 kPa).

(*) Refer to **Table 1** for description of gaseous and liquid O_2 adapts.

Related MIL Faults:

Pre-catalyst O_2 sensor errors / O_2 control errors
Dither valve DC faults / EST faults / ETC faults

Engine Cranking but Will Not Start / Difficult to Start

Engine cranks OK, but does not start for a long time. Does eventually run, or engine starts but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Be sure driver is using correct method to start engine as explained in operator's manual. Use "clear flood" mode during cranking by fully depressing the pedal and cranking the engine. If engine does not start, continue troubleshooting.

PROBABLE CAUSE	CORRECTIVE ACTION
Improper fuel selected	Verify "selected" fuel with Service Tool. Make sure fuel select switch is in proper position.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Liquid valve closed	Slowly open liquid valve.
Propane excess flow valve closed	Reset excess flow valve in LPG tank. Close liquid valve. Wait for a "click" sound; slowly open liquid valve.
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve. • Leak test.
Clogged fuel filter	Repair/replace as required. *See Chapter 4 Fuel Filter replacement.*
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Fuel lock-off malfunction	Repair/replace fuel lock-off. *See Chapter 4 Fuel Lock-off.*
Pressure regulator/converter malfunction	Test regulator/converter operation and pressure. *See Chapter 6 Tests and Adjustments.*
Incorrect air/fuel or ignition/spark control	*See Chapter 8 Advanced Diagnostics.*
No crankshaft position sensor signal	Verify the crankshaft position signal is present *See Chapter 8 Advanced Diagnostics.*

(continued on next page)

Engine Cranking but Will Not Start / Difficult to Start (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
SECM / control system malfunction	Check Engine Coolant Temperature (ECT) sensor using the Service Tool; compare coolant temperature with ambient temperature on cold engine. If coolant temperature reading is 5° greater than or less than ambient air temperature on a cold engine, check resistance in coolant sensor circuit or sensor itself. Compare ECT resistance value to "Diagnostic Aids" chart at end of this section. Verify that there is no code for Electronic Throttle Controller (ETC) spring check fault. Check for 0% APP during cranking. Cycle key ON and OFF and listen for throttle check (movement) on key OFF. Check for oil pressure switch faults. Check for ETC "sticking" faults. Check Throttle Position Sensor (TPS) for stuck binding or a high TPS voltage with the throttle closed.
Fuel system malfunction	Check fuel lock off (propane) or fuel pump. The lock off or fuel pump may turn "ON" for some seconds when ignition switch is turned "ON" (calibration specific). Check fuel pressure. Check for contaminated fuel. Check fuses (visually inspect). Check propane tank valve & pickup. A faulty in-tank fuel pump check valve will allow the fuel in the lines to drain back to the tank after engine is stopped. To check for this condition, perform fuel system diagnosis. Check FTV system for proper operation.
Ignition system malfunction	Check for proper ignition voltage output with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check for: • Bare or shorted wires. • Loose ignition coil ground. • Pickup coil resistance and connections.

Related MIL Faults:
ETC spring check / ETC faults / EST faults / TPS conflict

APP faults / Encoder error / MAP faults / Injector faults / Oil pressure faults

Lack of Power, Slow to Respond / Poor High Speed Performance / Hesitation During Acceleration

Engine delivers less than expected power. Little or no increase in speed when accelerator pedal is pushed down part way. Momentary lack of response as the accelerator is pushed down. May occur at all vehicle speeds. Usually most severe when first trying to make vehicle move, as from a stop. May cause engine to stall.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Drive vehicle; verify problem exists. Remove air filter and check for dirt or other means of plugging. Replace if needed.

PROBABLE CAUSE	**CORRECTIVE ACTION**
Fuel system malfunction	Check for restricted fuel filter. Check fuel supply. Check for LPG vapor from LPG liquid outlet valve on tank. Check for contaminated fuel. Check for clogged fuel filter and repair or replace as required. *See Chapter 4 Fuel Filter replacement* Check for plugged fuel line and remove any obstruction from the fuel line: • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve and leak test. Check for faulty vapor connection between pressure regulator/converter and mixer: • Verify that there are no holes in hose. • Observe that clamps are tight. • Look for kinked, pinched and/or collapsed hose. Monitor pre-catalyst O_2 with Service Tool. Check for proper pressure regulator operation. *See Chapter 6 Test and Adjustments.* Check for proper air/fuel mixer operation.
Ignition system malfunction	Check spark advance for excessive retarded ignition timing. Use Service Tool. Check secondary voltage using an oscilloscope or a spark tester to check for a weak coil. Check spark plug condition. Check poor spark plug primary and secondary wire condition.

(continued on next page)

Basic Troubleshooting (cont'd.)

Lack of Power, Slow to Respond / Poor High Speed Performance Hesitation During Acceleration (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Component malfunction	Check SECM grounds for cleanliness and secure connection. See SECM wiring diagrams. Check alternator output voltage. Repair if less than 9 volts or more than 16 volts. Check for clogged air filter and clean or replace as required. Check exhaust system for possible restriction. Refer to Chart T-1 on later pages. Inspect exhaust system for damaged or collapsed pipes. • Inspect muffler for heat distress or possible internal failure. • Check for possible plugged catalytic converter by comparing exhaust system backpressure on each side of engine. Check backpressure by removing Pre-catalyst O_2 sensor and measuring backpressure with a gauge.
Engine mechanical	*See Engine Manufacturer's Service Manual.* Check engine valve timing and compression Check engine for correct or worn camshaft.

Related MIL Faults:

EST faults
ETC faults
ETC spring check
TPS faults
APP faults
Encoder error
Delayed Shutdown faults

Detonation / Spark Knock

A mild to severe ping, usually worse under acceleration. The engine makes sharp metallic knocks that change with throttle opening (similar to the sound of hail striking a metal roof).

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for proper fuel level: • Check for LPG vapor from LPG liquid outlet valve on tank. • Fill fuel container. Do not exceed 80% of liquid capacity. Check fuel pressure. To determine if the condition is caused by a rich or lean system, the vehicle should be driven at the speed of the complaint. Monitoring with the Service tool will help identify problem.
Cooling system malfunction	Check for obvious overheating problems: • Low engine coolant. • Loose water pump belt. • Restricted air flow to radiator, or restricted water flow through radiator. • Inoperative electric cooling fan. • Correct coolant solution should be a mix of anti-freeze coolant (or equivalent) and water. • High coolant temperature.
Ignition system malfunction	Check ignition timing. Check spark module wiring.
Exhaust system malfunction	Check exhaust backpressure. Check for debris clogging the catalyst. Check that pre-catalyst O_2 sensor is functioning.
Engine mechanical	Check for excessive oil in the combustion chamber and/or blow by from excessive PCV flow. Check combustion chambers for excessive carbon build up. Check combustion chamber pressure by performing a compression test. Check for incorrect basic engine parts such as cam, heads, pistons, etc.

Related MIL Faults:

EST faults
Encoder error
High coolant temperature faults

Backfire

Fuel ignites in intake manifold or in exhaust system, making loud popping noise.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Simulate condition by reviewing operation procedure practiced by vehicle operator.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Perform fuel system diagnosis check: • Check for fuel leaks. • Check for MIL faults. • Check for damaged components.
Ignition system malfunction	Check proper ignition coil output voltage with spark tester. Check spark plugs. Remove spark plugs, check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary. Check spark plug wires for crossfire; also inspect spark plug wires and proper routing of plug wires. Check ignition timing.
Engine mechanical	Check compression: look for sticking or leaking valves. Check intake and exhaust manifold for casting flash and gasket misalignment. Refer to Engine Manufacturer's Service Manual.

Related MIL Faults: EST faults / ETC faults / Encoder error
Pre-catalyst O_2 sensor faults

Dieseling, Run-on

Engine continues to run after key is turned "OFF," but runs very roughly. If engine runs smoothly, check ignition switch and adjustment.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for fuel leaks or leaking injector.
Ignition switching	Make sure power to system is shut off when key is in OFF position.
Fuel lock off valve	Make sure lock off valve is closing properly.
Ignition system malfunction	Check spark advance at idle.

Related MIL Faults: EST faults / ETC faults / Pre-catalyst O_2 sensor faults

Rough, Unstable, Incorrect Idle, or Stalling

Engine cranks OK, but does not start for a long time. Does eventually run, or may start but immediately dies.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Check for vacuum leaks. Check that SECM grounds are clean and tight. See SECM wiring diagram.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Monitor oxygen feedback to help identify the cause of the problem. If the system is running lean or if the system is running rich evaluate further i.e. dither valve duty cycle and injector pulse width. Check for incorrect minimum idle speed that may be caused by foreign material accumulation in the throttle bore, on the throttle valve, or on the throttle shaft. Check that the injectors are clean and functioning. Check for liquid fuel in propane pressure regulator hose. If fuel is present, replace regulator assembly. The pre-catalyst oxygen (O_2) sensor should respond quickly to different throttle positions. If it does not, then check the pre-catalyst O_2 sensor for contamination. If the pre-catalyst O_2 sensor is aged or contaminated, the SECM will not deliver correct amount of fuel, resulting in a drivability problem.
Fuel container empty	Check for LPG vapor from LPG liquid outlet valve on tank. Fill fuel container. Do not exceed 80% of liquid capacity.
Ignition system malfunction	Check ignition system; wires, plugs, etc.
LPG pressure regulator malfunction	Test regulator operation and pressure. *See Chapter 6 Tests and Adjustments*
Air/fuel mixer malfunction	Check mixer.
Component malfunction	Check throttle for sticking or binding. Check PCV valve for proper operation by placing finger over inlet hole in valve end several times. Valve should snap back. If not, replace valve. Check alternator output voltage. Repair if less than 9 or more than 16 volts.
Engine mechanical	Perform a cylinder compression check. *See Engine Manufacturer's Service Manual.*

(continued on next page)

Rough, Unstable, Incorrect Idle, or Stalling (cont'd.)

PROBABLE CAUSE	CORRECTIVE ACTION
Excess flow valve closed	Reset excess flow valve. • Close liquid valve. • Wait for a "click" sound. Slowly open liquid valve.
Clogged fuel filter	Repair/replace as required *See Chapter 4 Fuel Filter Replacement*
Plugged fuel line	Remove obstruction from the fuel line. • Close liquid fuel valve. • Using caution, disconnect the fuel line (some propane may escape). • Clear obstruction with compressed air. • Re-connect fuel line. • Slowly open liquid fuel valve & leak test.
Fuel lock-off malfunction	Repair/replace fuel lock-off. *See Chapter 4 Fuel Lock-Off.*
Faulty vapor connection between the pressure regulator/converter and the mixer	Check connection. • Verify no holes in hose. • Clamps must be tight. • Look for kinked, pinched and/or collapsed hose.
Pressure regulator freezes	Check level in cooling system: • Must be full, check coolant strength. • -35°F (-37°C) minimum. Check coolant hoses. • Watch for kinks and/or pinched hoses. • Verify one pressure hose and one return hose. Test regulator. See Chapter 6
Vacuum leak	Check for vacuum leaks . . . • Between mixer and throttle body. • Between throttle body and intake manifold. • Between intake manifold and cylinder head.

Related MIL Faults:

EST faults
ETC Sticking fault
Pre-catalyst adapts error

Cuts Out, Misses

Steady pulsation or jerking that follows engine speed, usually more pronounced as engine load increases, sometimes above 1500 RPM. The exhaust has a steady spitting sound at idle or low speed.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check fuel system specifically for plugged fuel filter, low pressure. Check for contaminated fuel. Check injector drivers. Disconnect all injector harness connectors. Use injector test light or equivalent 6-volt test light between the harness terminals of each connector and observe if light blinks while cranking. If test light fails to blink at any connector, it is a faulty injector drive circuit harness, connector, or terminal. Check lock off for intermittent connection. Check dither valve operation.
Ignition system malfunction	Check for spark on the suspected cylinder(s) using a shop oscilloscope or spark tester or equivalent. If no spark, check for intermittent operation or miss. If there is a spark, remove spark plug(s) in these cylinders and check for cracks, wear, improper gap, burned electrodes, heavy deposits. Check spark plug wires by connecting ohmmeter to ends of each wire in question. If meter reads over 30,000 Ω, replace wire(s). Visually inspect wires for moisture, dust, cracks, burns, etc. Spray plug wires with fine water mist to check for shorts. Check engine ground wire for looseness or corrosion.
Component malfunction	Check for electromagnetic interference (EMI). A missing condition can be caused by EMI on the reference circuit. EMI can usually be detected by monitoring engine RPM with Service Tool. A sudden increase in RPM with little change in actual engine RPM indicates EMI is present. If problem exists, check routing of secondary wires and check distributor ground circuit. Check intake and exhaust manifolds for casting flash or gasket leaks.
Engine mechanical	Perform compression check on questionable cylinders. If compression is low, repair as necessary. Check base engine. Remove rocker covers and check for bent pushrods, worn rocker arms, broken valve springs, worn camshaft lobes, and valve timing. Repair as necessary.

Related MIL Faults:

EST faults
ETC Sticking fault

Basic Troubleshooting (cont'd.)

Poor Fuel Economy / Excessive Fuel Consumption
LPG Exhaust Smell

Fuel economy, as measured during normal operation, is noticeably lower than expected. Also, economy is noticeably lower than what it has been in the past. Propane fuel smell near vehicle sets off carbon monoxide sensors.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter. Verify operator complaint: identify operating conditions. Check operator's driving habits: Are tires at correct pressure? Are excessively heavy loads being carried? Is acceleration too much, too often? Check air cleaner element (filter) for being dirty or plugged. Visually (physically) check vacuum hoses for splits, kinks, and proper connections.

PROBABLE CAUSE	CORRECTIVE ACTION
Fuel system malfunction	Check for faulty gasoline pressure regulator. Check for leaking injector. Check that dither valve duty cycle is < 15%. Check for too high propane pressure at mixer (> 1" positive pressure). Monitor Pre-catalyst O_2 sensor with Service Tool.
Cooling system malfunction	Check engine coolant level. Check engine thermostat for faulty part (always open) or for wrong heat range.
Ignition system malfunction	Check ignition timing. Check for weak ignition and/or spark control. Check spark plugs. Remove spark plugs and check for wet plugs, cracks, wear, improper gap, burned electrodes, or heavy deposits. Repair or replace as necessary.
Component malfunction	Check for exhaust system restriction or leaks. Check induction system and crankcase for air leaks. Check for clogged air filter; clean or replace as required. Check FTVs for housing cracks or obstructions; repair or replace as required. Check for vacuum leak. Check system vacuum hoses from regulator to FTVs and mixer. Repair or replace as required.
Air/fuel mixer malfunction	Check mixer.
Pressure regulator malfunction / fuel pressure too high	Test regulator operation and pressure. *See Chapter 6 Tests and Adjustments.*
Engine mechanical	Check compression. *Refer to Engine Manufacturer's Service Manual.*

Related MIL Faults:

Pre-catalyst O_2 sensor faults / Low side driver / Dither valve duty cycle
EST faults / Fuel adapt faults / Low coolant temperature

High Idle Speed

Engine idles above the range of 750-1000 RPM.

PRELIMINARY CHECKS
Perform the visual checks as described at start of " Basic Troubleshooting" chapter.

PROBABLE CAUSE	CORRECTIVE ACTION
Incorrect idle speed control	Check all hoses and gaskets for cracking, kinks, or leaks. Verify that there are no vacuum leaks. *See Chapter 8 Advanced Diagnostics & Chapter 6 Tests and Adjustments*
Throttle sticking	Replace throttle. *See Fault Code 461: ETC Sticking*
Foot pedal sticking or incorrect pedal signal	Check pedal return spring travel for binding. Check APP function with Service Tool. Verify smooth change of APP reading with pedal movement. *See Chapter 8 Advanced Diagnostics.*
Engine mechanical	Check for vacuum hose leak. Check for PCV malfunction. Check for defective intake gasket.

Related MIL Faults:

ETC Sticking fault
Idle adapt out of range
MAP Sticking fault
MAP high value

Excessive Exhaust Emissions or Odors

Vehicle has high CO emissions.
NOTE: Excessive odors do not necessarily indicate excessive emissions.

PRELIMINARY CHECKS
Verify that no stored codes exist. If emission test shows excessive CO and HC, check items that cause vehicle to run **rich**. If emission test shows excessive NOx, check items that cause vehicle to run **lean** or too hot.

PROBABLE CAUSE	CORRECTIVE ACTION
Cooling system malfunction	If the Service tool indicates a very high coolant temperature and the system is running *lean*: • Check engine coolant level. • Check engine thermostat for faulty part (always open) or for wrong heat range. • Check fan operation
Fuel system malfunction	If the system is running *rich*, refer to "Diagnostic Aids" chart on the next page. If the system is running *lean* refer to "Diagnostic Aids" chart on the next page. Check for properly installed fuel system components. Check fuel pressure.
Ignition system malfunction	Check ignition timing. Check spark plugs, plug wires, and ignition components.
Component malfunction	Check for vacuum leaks. Check for contamination for catalytic converter (look for the removal of fuel filler neck restrictor). Check for carbon build-up. Remove carbon with quality engine cleaner. Follow instructions on label. Check for plugged PCV valve. Check for stuck or blocked PCV hose. Check for fuel in the crankcase.

Related MIL Faults:

Low side driver
Fuel adapt faults
EST faults

Diagnostic Aids for Rich / Lean Operation

SERVICE TOOL ITEM	RICH	LEAN
Pre-catalyst O_2 A/ D counts	Consistently > 250	Consistently < 170
Pre-catalyst O2 sensor switching between high and low	Always high ADC	Always low ADC
Trim valve duty cycle	> 90%	< 10%
Fuel injector pulse width at idle *	< 1.0 msec.	> 8 msec.
Malfunction codes	• Pre-catalyst O_2 sensor failed rich • Pre-catalyst O_2 sensor high • Fuel adapts	• Pre-catalyst O_2 sensor failed lean • Pre-catalyst O_2 sensor low • Fuel adapts
Closed loop operation	Stuck in open loop	Stuck in open loop

(*) The duty cycle injector pulse width criteria for lean or rich operation apply only if the O_2 sensor is functioning properly. If the sensor is not operating properly the criteria may be reversed.

RICH OPERATION

LP (Trim valve duty cycle>90%)

- Inspect hoses from AVV port (port on bottom of mixer) to trim valves and regulator for leaks or blockages, replace as necessary.
- Inspect in-line orifices for blockages (in wye), replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec
- Inspect fuel cone for damage, replace mixer assembly as necessary

Gasoline (Injector Pulse Width<1.0 msec)

- Check gasoline fuel pressure
- Check injectors for sticking, replace as necessary

LEAN OPERATION

LP (Trim valve duty cycle<10%)

- Check for vacuum leaks, replace hoses, o-rings, and gaskets as necessary
- Check balance line for blockage, replace as necessary
- Check vapor hose for restrictions, replace as necessary
- Check trim valves for proper operation, replace as necessary
- Check regulator out pressure, replace if out of spec

Gasoline (Injector Pulse Width>8 msec)

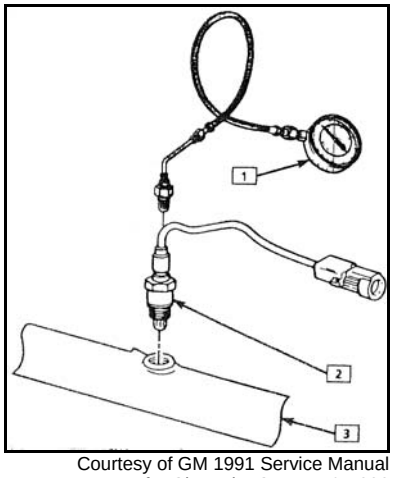
- Check system voltage
- Check fuel pressure
- Check injectors for sticking or obstructions

Chart T-1
Restricted Exhaust System Check

Proper diagnosis for a restricted exhaust system is essential before replacement of any components. The following procedures may be used for diagnosis, depending upon engine or tool used.

CHECK AT PRE-CATALYST OXYGEN (O_2) SENSOR

1. Carefully remove pre-catalyst oxygen (O_2) sensor.
2. Install exhaust backpressure tester or equivalent in place of O_2 sensor using Snap-On P/N EEVPV311A kit and YA8661 adapter or Mac tool (see illustration).
3. After completing test described below, be sure to coat threads of O_2 sensor with anti-seize compound prior to re-installation.



Courtesy of GM 1991 Service Manual
for Chevrolet Camaro © 1990

ILLUSTRATION NOTES

[1] Backpressure gage
[2] Pre-catalyst Oxygen (O_2) sensor
[3] Exhaust manifold

DIAGNOSIS:

1. With the engine idling at normal operating temperature, observe the exhaust system backpressure reading on the gage. Reading should not exceed 1.25 psig (8.61 kPa).
2. Increase engine speed to 2000 RPM and observe gage. Reading should not exceed 3 psig (20.68 kPa).
3. If the backpressure at either speed exceeds specification, a restricted exhaust system is indicated.
4. Inspect the entire exhaust system for a collapsed pipe, heat distress, or possible internal damage, split welds, or cracked pipe.
5. If there are no obvious reasons for the excessive backpressure, the catalytic converter is restricted and should be replaced using current recommended procedures.

Chapter 8.
Advanced Diagnostics

MI-07 systems are equipped with built-in fault diagnostics. Detected system faults can be displayed by the Malfunction Indicator Lamp (MIL) as Diagnostic Fault Codes (DFC) or flash codes, and viewed in detail with the use of the Service Tool software. When the ignition key is turned on, the MIL will illuminate and remain on until the engine is started. Once the engine is started, the MIL lamp will go out unless one or more fault conditions are present. If a detected fault condition exists, the fault or faults will be stored in the memory of the small engine control module (SECM). Once an active fault occurs the MIL will illuminate and remain ON. This signals the operator that a fault has been detected by the SECM.

Reading Diagnostic Fault Codes

All MI-07 fault codes are three-digit codes. When the fault codes are retrieved (displayed) the MIL will flash for each digit with a short pause (0.5 seconds) between digits and a long pause (1.2 seconds) between fault codes. A code 12 is displayed at the end of the code list.

EXAMPLE: A code 461 (ETC Sticking) has been detected and the engine has shut down and the MIL has remained **ON**. When the codes are displayed the MIL will flash four times (**4**), pause, then flash six times (**6**), pause, then flash one time (**1**) This identifies a four sixty one (**461**), which is the ETC Sticking fault. If any additional faults were stored, the SECM would again have a long pause, then display the next fault by flashing each digit. Since no other faults were stored there will be a long pause then one flash (**1**), pause, then two flashes (**2**). This identifies a twelve, signifying the end of the fault list. This list will then repeat.

Displaying Fault Codes (DFC) from SECM Memory

To enter code display mode you must turn **OFF** the ignition key. Now turn **ON** the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal three (**3**) times within five (**5**) seconds to enable the display codes feature of the SECM. Simply turn the key **OFF** to exit display mode. The code list will continue to repeat until the key is turned **OFF**.

Clearing Fault (DFC) Codes

To clear the stored fault codes from SECM memory you must complete the reset fault pedal maneuver.

CAUTION
Once the fault list is cleared it cannot be restored.

First turn **OFF** the ignition key. Now turn **ON** the key but do not start the engine. As soon as you turn the key to the ON position you must cycle the foot pedal by depressing it to the floor and then fully releasing the pedal (pedal maneuver). You must fully cycle the foot pedal ten (**10**) times within five (**5**) seconds to clear the fault code list of the SECM. Simply turn the key **OFF** to exit the reset mode.

The code list is now clear and the SECM will begin storing new fault codes as they occur.

Fault Action Descriptions

Each fault detected by the SECM is stored in memory (FIFO) and has a specific action or result that takes place. Listed below are the descriptions of each fault action.

Engine Shutdown: The most severe action is an Engine Shutdown. The MIL will light and the engine will immediately shutdown, stopping spark, closing the fuel lock-off, and turning off the fuel pump and fuel injectors.

Delayed Engine Shutdown: Some faults, such as low oil pressure, will cause the MIL to illuminate for 30 seconds and then shut down the engine.

Cut Throttle: The throttle moves to its default position. The engine will run at idle but will not accelerate.

Turn on MIL: The MIL will light by an active low signal provided by the SECM, indicating a fault condition. The MIL may illuminate with no other action or may be combined with other actions, depending on which fault is active.

Soft Rev Limit / Medium Rev Limit / Hard Rev Limit: System will follow various sequences to bring engine speed back to acceptable levels.

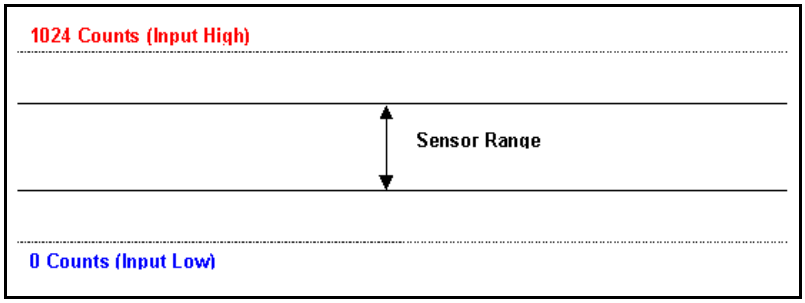
Level4 Power Limit / Level3 Power Limit / Level2 Power Limit / Level1 Power Limit: The maximum engine power output will be limited to one of four possible levels. The engine power is calculated from measured engine parameters (e.g. MAP, RPM, fuel flow, etc).

Disable Gas O_2 Control: In LPG mode, closed loop correction of the air fuel ratio based on the Pre-catalyst O_2 sensor is disabled.

Disable Liquid O_2 Control: In Gasoline mode, closed loop correction of the air fuel ratio based on the Pre-catalyst O_2 sensor is disabled.

Fault List Definitions

All the analog sensors in the MI-07 system have input sensor range faults. These are the coolant temperature sensor, fuel temperature sensor, throttle position sensors, pedal position sensors, manifold pressure sensor, HEGO sensors, and intake air temperature sensor. Signals to these sensors are converted into digital counts by the SECM. A low/high range sensor fault is normally set when the converted digital counts reach the minimum of 0 or the maximum of 1024 (**1024 = 5.0 Vdc with ~ 204 counts per volt**).



Additionally, the SECM includes software to learn the actual range of the pedal position and throttle position sensors in order to take full advantage of the sensor range. Faults are set if the learned values are outside of the normal expected range of the sensor (e.g. APP1AdaptLoMin).

Table 1. Fault List Definitions

FAULT	DESCRIPTION	CODE (MI04 CODE)
APP1AdaptHiMax	Learned full pedal value of APP_1 sensor range higher than expected	641 (64)
APP1AdaptHiMin	Learned full pedal value of APP_1 sensor range lower than expected	651
APP1AdaptLoMax	Learned idle value of APP_1 sensor range higher than expected	661
APP1AdaptLoMin	Learned idle value of APP_1 sensor range lower than expected	631 (63)
APP1RangeHigh	APP_1 sensor voltage out of range high, normally set if the APP_1 signal has shorted to power or the ground for the sensor has opened	621 (62)
APP1RangeLow	APP_1 sensor voltage out of range low, normally set if the APP_1 signal has shorted to ground, circuit has opened or sensor has failed	611 (61)
APP2AdaptHiMax	Learned full pedal value of APP_2 sensor range higher than expected	642 (68)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
APP2AdaptHiMin	Learned full pedal value of APP_2 sensor range lower than expected	652
APP2AdaptLoMax	Learned idle value of APP_2 sensor range higher than expected	662
APP2AdaptLoMin	Learned idle value of APP_2 sensor range lower than expected	632 (67)
APP2RangeHigh	APP_2 sensor voltage out of range high, normally set if the APP_2 signal has shorted to power or the ground for the sensor has opened	622 (66)
APP2RangeLow	APP_2 sensor voltage out of range low, normally set if the APP_2 signal has shorted to ground, circuit has opened or sensor has failed	612 (65)
APP_Sensors_Conflict	APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	691 (69)
CamEdgesFault	No CAM signal when engine is known to be rotating, broken CAM sensor leads or defective CAM sensor	191
CamSyncFault	Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	192
CrankEdgesFault	No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	193
CrankSyncFault	Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	194
ECTOverTempFault	Engine Coolant Temperature is High. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	161 (16)
ECTRangeHigh	Engine Coolant Temperature Sensor Input is High. Normally set if coolant sensor wire has been disconnected or circuit has opened to the SECM.	151 (15)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
ECTRangeLow	Engine Coolant Temperature Sensor Input is Low. Normally set if the coolant sensor wire has shorted to chassis ground or the sensor has failed.	141 (14)
ECT_IR_Fault	Engine Coolant Temperature not changing as expected	171
EST1_Open	EST1 output open, possibly open EST1 signal or defective spark module	421
EST1_Short	EST1 output shorted high or low, EST1 signal shorted to ground or power or defective spark module	431 (42)
ETCSpringTest	Electronic Throttle Control Spring Return Test has Failed. The SECM will perform a safety test of the throttle return spring following engine shutdown. If this spring has become weak the throttle will fail the test and set the fault. **NOTE: Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly**.	481 (28)
ETC_Open_Fault	Electronic Throttle Control Driver has failed. Normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	471
ETC_Sticking	Electronic Throttle Control is Sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction; a loose throttle plate or worn components shaft bearings. ***NOTE: Throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	461 (26)
FuelSelectConflict	Conflict in fuel select signals, normally set if one or both of the fuel select signals are shorted to ground	181
FuelTempRangeHigh	Fuel Temperature Sensor Input is High. Normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	932
FuelTempRangeLow	Fuel Temperature Sensor Input is Low. Normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	931
GasFuelAdaptRangeHi	In LPG mode, system had to adapt lean more than expected	731 (73)
GasFuelAdaptRangeLo	In LPG mode, system had to adapt rich more than expected	721 (72)
GasO2FailedLean	Pre-catalyst O_2 sensor indicates extended lean operation on LPG	751

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
GasO2FailedLean	Pre-catalyst O_2 sensor indicates extended lean operation on LPG	751
GasO2FailedRich	Pre-catalyst O_2 sensor indicates extended rich operation on LPG	771 (77)
GasO2NotActive	Pre-catalyst O_2 sensor inactive on LPG, open O_2 sensor signal or heater leads, defective O_2 sensor, or defective FTVs	741 (74)
GasPostO2FailedRich	Post-catalyst O_2 sensor control on LPG has reached rich limit and sensor still reads too lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	772
GasPostO2FailedLean	Post-catalyst O_2 sensor control on LPG has reached lean limit and sensor still reads too rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set diagnose, these first and after correcting these faults recheck if this fault sets.	752
GasPostO2Inactive	Post-catalyst O_2 sensor control on LPG has sensed the O_2 sensor is not responding as expected. If any Pre-O_2 sensor faults are set diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	742
Reserved for Future Use		743
HbridgeFault_ETC	(Electronic Throttle Control Driver has Failed) Indeterminate fault on Hbridge driver for Electronic Throttle Control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	491 (29)
HardOverspeed	Engine speed has exceeded the third level (3 of 3) of overspeed protection	571 (57)

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
IATRangeHigh	Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected, the circuit has opened to the SECM, or a short to Vbatt has occurred.	381 (38)
IATRangeLow	Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	371 (37)
IAT_IR_Fault	Intake Air Temperature not changing as expected	391
Inj1Open	Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	131
Inj2Open	Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	132
Inj3Open	Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	133
LSDFault_CrankDisable	Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	715
LSDFault_Dither1	Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	711 (71)
LSDFault_Dither2	Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	712
LSDFault_FuelPump	Fuel Pump Fault, signal has opened or shorted to ground or power or defective fuel pump	716
LSDFault_LockOff	Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	717
LSDFault_MIL	Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	718
LiqFuelAdaptRangeHi	In Gasoline mode, system had to adapt rich more than expected	821
LiqFuelAdaptRangeLow	In Gasoline mode, system had to adapt lean more than expected	831
LiqO2FailedLean	Pre-catalyst O_2 sensor indicates extended lean operation on gasoline	851
LiqO2FailedRich	Pre-catalyst O_2 sensor indicates extended rich operation on gasoline	871

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
LiqO2NotActive	Pre-catalyst O_2 sensor inactive on gasoline, open O_2 sensor signal or heater leads, defective O_2 sensor	841
LiqPostO2FailedRich	Post-catalyst O_2 sensor control on gasoline has reached rich limit and sensor still reads too lean. This could be caused by oxygen leak before or just after sensor, catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	872
LiqPostO2FailedLean	Post-catalyst O_2 sensor control on gasoline has reached lean limit and sensor still reads too rich. This could be caused by catalyst failure, sensor failure, or wiring/relay failure causing the sensor to not be properly heated. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets.	852
LiqPostO2Inactive	Post-catalyst O_2 sensor control on gasoline has sensed the O_2 sensor is not responding as expected. If any Pre-O_2 sensor faults are set, diagnose these first and after correcting these faults recheck if this fault sets. Possible causes for this fault are sensor disconnected, sensor heater failed, sensor element failed, heater relay, or SECM control of heater relay is disconnected or failed.	842
Reserved		843
LowOilPressureFault	Low engine oil pressure	521 (52)
MAPRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	342
MAPRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	332
MAPTimeRangeHigh	Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	341 (34)
MAPTimeRangeLow	Manifold Absolute Pressure Sensor Input is Low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	331 (33)
MAP_IR_HI	MAP sensor indicates higher pressure than expected	351
MAP_IR_LO	MAP sensor indicates lower pressure than expected	352

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
MAP_STICKING	MAP sensor not changing as expected	353
MediumOverspeed	Engine speed has exceeded the second level (2 of 3) of overspeed protection	572
O2RangeHigh	Pre-catalyst O_2 sensor voltage out of range high, sensor signal shorted to power	921
O2RangeLow	Pre-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	911
O2_PostCatRangeHigh	Post-catalyst O_2 sensor voltage out of range high, sensor signal shorted to voltage source (5V or battery)	922
O2_PostCatRangeLow	Post-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	912
SensVoltRangeHigh	Sensor reference voltage XDRP too high	561 (56)
SensVoltRangeLow	Sensor reference voltage XDRP too low	551 (55)
ServiceFault1	Service Interval 1 has been reached	991
ServiceFault2	Service Interval 2 has been reached	992
ServiceFault3	Service Interval 3 has been reached	993
ServiceFault4	Service Interval 4 has been reached—time to replace HEGO sensors	994
ServiceFault5	Service Interval 5 has been reached	995
SoftOverspeed	Engine speed has exceeded first level (1 of 3) of overspeed protection	573
TPS1AdaptHiMin	Learned WOT value of TPS_1 sensor range lower than expected	271
SysVoltRangeHigh	System voltage too high	541 (54)
SysVoltRangeLow	System voltage too low	531 (53)
TPS1AdaptHiMax	Learned WOT value of TPS_1 sensor range higher than expected	251 (25)
TPS1AdaptHiMin	Learned WOT value of TPS_1 sensor range lower than expected	271
TPS1AdaptLoMax	Learned closed throttle value of TPS_1 sensor range higher than expected	281
TPS1AdaptLoMin	Learned closed throttle value of TPS_1 sensor range lower than expected	241 (24)
TPS1RangeHigh	TPS_1 sensor voltage out of range high, normally set if the TPS_1 signal has shorted to power or ground for the sensor has opened	231 (23)
TPS1RangeLow	TPS_1 sensor voltage out of range low, normally set if TPS_1 signal has shorted to ground, circuit has opened or sensor has failed	221 (22)
TPS2AdaptHiMax	Learned WOT value of TPS_2 sensor range higher than expected	252

TPS2AdaptHiMin	Learned WOT value of TPS_2 sensor range lower than expected	272

Table 1. Fault List Definitions (cont'd.)

FAULT	DESCRIPTION	CODE (MI04 CODE)
TPS2AdaptLoMax	Learned closed throttle value of TPS_2 sensor range higher than expected	282
TPS2AdaptLoMin	Learned closed throttle value of TPS_2 sensor range lower than expected	242
TPS2RangeHigh	TPS_2 sensor voltage out of range high, normally set if the TPS_2 signal has shorted to power or ground for the sensor has opened	232
TPS2RangeLow	TPS_2 sensor voltage out of range low, normally set if TPS_2 signal has shorted to ground, circuit has opened or sensor has failed	222
TPS_Sensors_Conflict	TPS sensors differ by more than expected amount. ***NOTE: The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly***	291

Table 2. Diagnostic Fault Codes (Flash Codes)

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
12	**NONE** Signifies the end of one pass through the fault list	NONE	None, used as end of the fault list identification
131	**Inj1Open** Gasoline Injector 1 open circuit, broken injector 1 wire or defective injector	TurnOnMil	Check INJ1 wiring for an open circuit SECM (Signal) A5 to Injector 1 Pin A Switched 12V to Injector 1 Pin B Check Injector 1 Resistance, 12 to14 ohms (cold)
132	**Inj2Open** Gasoline Injector 2 open circuit, broken injector 2 wire or defective injector	TurnOnMil	Check INJ2 wiring for an open circuit SECM (Signal) A4 to Injector 2 Pin A Switched 12V to Injector 2 Pin B Check Injector 2 Resistance, 12 to14 ohms (cold)
133	**Inj3Open** Gasoline Injector 3 open circuit, broken injector 3 wire or defective injector	TurnOnMil	Check INJ3 wiring for an open circuit SECM (Signal) A to Injector 3 Pin A Switched 12V to Injector 3 Pin B Check Injector 3 Resistance, 12 to14 ohms (cold)
141 (14)	**ECTRangeLow** Coolant Sensor failure or shorted to GND	TurnOnMil	Check ECT sensor connector and wiring for a short to GND SECM (Signal) Pin B15 To ECT Pin A SECM (Sensor GND) Pin B1 to ECT Pin B SECM (System GND) Pin A16, B17
151 (15)	**ECTRangeHigh** Coolant sensor disconnected or open circuit	(1) TurnOnMil (2) DelayedEngine Shutdown (3) CheckEngineLight	Check if ECT sensor connector is disconnected or for an open ECT circuit SECM (Signal) Pin B15 to ECT Pin A SECM (Sensor GND) Pin B1 to ECT Pin B

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
161 (16)	**ECTOverTempFault** Engine coolant temperature is high. The sensor has measured an excessive coolant temperature typically due to the engine overheating.	(1) TurnOnMil (2) DelayedEngine Shutdown (3) CheckEngineLight	Check coolant system for radiator blockage, proper coolant level and for leaks in the system. Possible ECT short to GND, check ECT signal wiring SECM (Signal) Pin B15 to ECT Pin A SECM (Sensor GND) Pin B1 to ECT Pin B SECM (System GND) Pin A16, B17 Check regulator for coolant leaks
171	**ECT_IR_Fault** Engine coolant temperature not changing as expected	None	Check for coolant system problems, e.g. defective or stuck thermostat
181	**FuelSelectConflict** Conflict in fuel select signals, normally set if both of the fuel select signals are shorted to ground	TurnOnMil	Check fuel select switch connection for a short to GND SECM (SIGNAL) Pin A12 SECM (SIGNAL) Pin A15 SECM (Sensor GND) Pin B1
191	**CamEdgesFault** No CAM signal when engine is known to be rotating, broken crankshaft sensor leads or defective CAM sensor	None	Check CAM sensor connections at distributor SECM (SIGNAL) Pin B10 to distributor connector Pin B SECM (Sensor GND) Pin B1 to distributor connector Pin A SECM 5V (PWR) to distributor connector Pin C Check for defective CAM sensor in distributor housing.
192	**CamSyncFault** Loss of synchronization on the CAM sensor, normally due to noise on the signal or an intermittent connection on the CAM sensor	None	Check CAM sensor connections at distributor SECM (SIGNAL) Pin B10 to distributor connector Pin B SECM (Sensor GND) Pin B1 to distributor connector Pin A SECM 5V (PWR) to distributor connector Pin C Check for defective CAM sensor in distributor housing
193	**CrankEdgesFault** No crankshaft signal when engine is known to be rotating, broken crankshaft sensor leads or defective crank sensor	None	Check Crankshaft sensor connections SECM (SIGNAL) Pin B5 to Crank sensor Pin C SECM (Sensor GND) PIN B1 to Crank sensor Pin B SECM 5V (PWR) to Crank sensor Pin A Check for defective Crank sensor

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
194	**CrankSyncFault** Loss of synchronization on the crankshaft sensor, normally due to noise on the signal or an intermittent connection on the crankshaft sensor	None	Check Crankshaft sensor connections SECM (SIGNAL) Pin B5 to Crank sensor Pin C SECM (Sensor GND) Pin B1 to Crank sensor Pin B SECM 5V (PWR) to Crank sensor Pin A Check for defective Crank sensor
221 (22)	**TPS1RangeLow** TPS_1 sensor voltage out of range low, normally set if the TPS_1 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check throttle connector connection and TPS_1 sensor for an open circuit or short to GND SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (sensor GND) to ETC Pin 2 SECM (system GND) Pin A16, B17
222	**TPS2RangeLow** TPS_2 sensor voltage out of range low, normally set if the TPS_2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check throttle connector connection and TPS_2 sensor for an open circuit or short to GND SECM Pin B4 (signal) to ETC Pin 5 SECM Pin B1 (sensor GND) to ETC Pin 2 SECM (system GND) Pin A16, B17
231 (23)	**TPS1RangeHigh** TPS_1 sensor voltage out of range high, normally set if the TPS_1 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check throttle connector and TPS_1 sensor wiring for a shorted circuit SECM Pin B23 (signal) to ETC Pin 6 SECM Pin B1 (sensor GND) to ETC Pin 2
232	**TPS2RangeHigh** TPS_2 sensor voltage out of range high, normally set if the TPS_2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check throttle connector and TPS_1 sensor wiring for a shorted circuit SECM Pin B4 (signal) to ETC Pin 5 SECM pin B1 (sensor GND) to ETC Pin 2
241 (24)	**TPS1AdaptLoMin** Learned closed throttle value of TPS_1 sensor range lower than expected	None	Check the throttle connector and pins for corrosion. To check the TPS disconnect the throttle connector and measure the resistance from: TPS Pin 2 (GND) to Pin 6 (TPS_1 SIGNAL) (0.7 Ω ± 30%) TPS Pin 3 (PWR) to Pin 6 (TPS_1 SIGNAL) (1.4 Ω ± 30%)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
42	**TPS2AdaptLoMin** Learned closed throttle value of TPS_2 sensor range lower than expected	None	Check the throttle connector and pins for corrosion. To check the TPS disconnect the throttle connector and measure the resistance from: TPS Pin 2 (GND) to Pin 5 (TPS_2 SIGNAL) (1.3K Ω ± 30%) TPS PIN 3 (PWR) to PIN 5 (TPS_2 SIGNAL) (0.6K Ω ± 30%)
251 (25)	**TPS1AdaptHiMax** Learned WOT value of TPS_1 sensor range higher than expected	None	N/A
252	**TPS2AdaptHiMax** Learned WOT value of TPS_2 sensor range higher than expected	None	N/A
271	**TPS1AdaptHiMin** Learned WOT value of TPS_1 sensor range lower than expected	None	N/A
272	**TPS2AdaptHiMin** Learned WOT value of TPS_2 sensor range lower than expected	None	N/A
281	**TPS1AdaptLoMax** Learned closed throttle value of TPS_1 sensor range higher than expected	None	N/A
282	**TPS2AdaptLoMax** Learned closed throttle value of TPS_2 sensor range higher than expected	None	N/A
291	**TPS_Sensors_Conflict** TPS sensors differ by more than expected amount **NOTE: *The TPS is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	(1) TurnOnMil (2) Engine Shutdown	Perform checks for DFCs 241 & 242

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
331 (33)	**MAPTimeRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	None	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (PWR) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal kPa) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (PWR) to Pin 4 (pressure signal kPa) (3.4kΩ - 8.2kΩ)
332	**MAPRangeLow** Manifold Absolute Pressure sensor input is low, normally set if the TMAP pressure signal wire has been disconnected or shorted to ground or the circuit has opened to the SECM	(1) TurnOnMil (2) CutThrottle	Check TMAP connector and MAP signal wiring for an open circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (PWR) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal kPa) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal kPa) (3.4kΩ - 8.2kΩ)
341 (34)	**MAPTimeRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed.	None	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (PWR) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal kPa) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal kPa) (3.4kΩ - 8.2kΩ)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION, FIRST CHECK
342	**MAPRangeHigh** Manifold Absolute Pressure Sensor Input is High, normally set if the TMAP pressure signal wire has become shorted to power, shorted to the IAT signal, the TMAP has failed or the SECM has failed	(1) TurnOnMil (2) CutThrottle	Check TMAP connector and MAP signal wiring for a shorted circuit TMAP Pin 4 to SECM Pin B18 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) TMAP Pin 3 to SECM Pin B24 (PWR) Check the MAP sensor by disconnecting the TMAP connector and measuring at the sensor: TMAP Pin 1(GND) to Pin 4 (pressure signal kPa) (2.4kΩ - 8.2kΩ) TMAP Pin 3 (power) to Pin 4 (pressure signal kPa) (3.4kΩ - 8.2kΩ)
351	**MAP_IR_HI** MAP sensor indicates higher pressure than expected	None	Check for vacuum leaks. Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
352	**MAP_IR_LO** MAP sensor indicates lower pressure than expected	None	Possible defective TMAP sensor.
353	**MAP_STICKING** MAP sensor not changing as expected	None	Check that TMAP sensor is mounted properly. Possible defective TMAP sensor.
371 (37)	**IATRangeLow** Intake Air Temperature Sensor Input is Low normally set if the IAT temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 to SECM Pin B12 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.
381 (38)	**IATRangeHigh** Intake Air Temperature Sensor Input is High normally set if the IAT temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check TMAP connector and IAT signal wiring for a shorted circuit TMAP Pin 2 to SECM Pin B12 (signal) TMAP Pin 1 to SECM Pin B1 (sensor GND) To check the IAT sensor of the TMAP disconnect the TMAP connector and measure the IAT resistance Resistance is approx 2400 ohms at room temperature.
391	**IAT_IR_Fault** Intake Air Temperature not changing as expected	None	Check connections to TMAP sensor. Check that TMAP sensor is properly mounted to manifold.

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
421	**EST1_Open** EST1 output open, possibly open EST1 signal or defective spark module	TurnOnMil	Check ignition module wiring and connector for open circuit SECM Pin A9 (EST1) to ignition module Pin B. Verify GND on ignition module Pin C Verify +12 Vdc on ignition module Pin A Refer to application manual for specific engine details.
431 (42)	**EST1_Short** EST1 output shorted high or low, EST1 signal shorted to ground or power or defective spark module	TurnOnMil	Check ignition module wiring and connector for shorts SECM Pin A9 (EST1) to ignition module Pin B Verify GND on ignition module Pin C Verify +12 Vdc on ignition module Pin A Refer to application manual for specific engine details.
461 (26)	**ETC_Sticking** Electronic Throttle Control is sticking. This can occur if the throttle plate (butterfly valve) inside the throttle bore is sticking. The plate sticking can be due to some type of obstruction, a loose throttle plate, or worn components shaft bearings. **NOTE: *The throttle assembly is not a serviceable item and can only be repaired by replacing the DV-EV throttle assembly.***	(1) TurnOnMil (2) EngineShutdown (3) CutThrottle	Check for debris or obstructions inside the throttle body • Check throttle-plate shaft for bearing wear Check the ETC driver wiring for an open circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle ETC Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0Ω
471	**ETC_Open_Fault** Electronic Throttle Control Driver has failed, normally set if either of the ETC driver signals have opened or become disconnected, electronic throttle or SECM is defective.	None	Check the ETC driver wiring for an open circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle ETC Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0Ω

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
491 (29)	**HbridgeFault_ETC** Electronic Throttle Control Driver has failed. Indeterminate fault on Hbridge driver for electronic throttle control. Possibly either ETC+ or ETC- driver signals have been shorted to ground	TurnOnMil	Check ETC driver wiring for a shorted circuit SECM Pin A17 to ETC + Pin 1 SECM Pin A18 to ETC - Pin 4 Check the ETC internal motor drive by disconnecting the throttle connector and measuring the motor drive resistance at the throttle ETC Pin 1 (+DRIVER) to Pin 4 (-DRIVER) ~3.0-4.0Ω
521 (52)	**LowOilPressureFault** Low engine oil pressure	(1) TurnOnMil (2) DelayedEngine Shutdown (3) CheckEngine Light	Check engine oil level Check electrical connection to the oil pressure switch SECM Pin B9 to Oil Pressure Switch
531 (53)	**SysVoltRangeLow** System voltage too low	TurnOnMil	Check battery voltage • Perform maintenance check on electrical connections to the battery and chassis ground • Check battery voltage during starting and when the engine is running to verify charging system and alternator function • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (DRVP) to SECM Pin A16 (DRVG) SECM Pin A23 (DRVP) to SECM Pin B17 (DRVG)
541 (54)	**SysVoltRangeHigh** System voltage too high	TurnOnMil	Check battery and charging system voltage • Check battery voltage during starting and when the engine is running • Check voltage regulator, alternator, and charging system • Check battery and wiring for overheating and damage • Measure battery power at SECM with a multimeter (with key on) SECM Pin A23 (DRVP) to SECM Pin A16 (DRVG) SECM Pin A23 (DRVP) to SECM Pin B17 (DRVG)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
551 (55)	**SensVoltRangeLow** Sensor reference voltage XDRP too low	(1) TurnOnMil (2) EngineShutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 (PWR) to TMAP Pin 1 (sensor GND) Verify transducer power at the SECM with a multimeter SECM Pin B24 (PWR) to SECM Pin B1 (sensor GND) Verify transducer power at ETC with a multimeter ETC Pin 3 (PWR) to ETC Pin 2 (sensor GND) Verify transducer power to the foot pedal with a multimeter.
561 (56)	**SensVoltRangeHigh** Sensor reference voltage XDRP too high	(1) TurnOnMil (2) EngineShutdown	Measure transducer power at the TMAP connector with a multimeter TMAP Pin 3 (PWR) to TMAP Pin 1 (sensor GND) Verify transducer power at the SECM with a multimeter SECM Pin B24 (PWR) to SECM Pin B1 (sensor GND) Verify transducer power at ETC with a multimeter ETC Pin 3 (PWR) to ETC Pin 2 (sensor GND) Verify transducer power to the foot pedal with a multimeter.
571 (57)	**HardOverspeed** Engine speed has exceeded the third level (3 of 3) of overspeed protection	(1) TurnOnMil (2) HardRevLimit	Usually associated with additional ETC faults • Check for ETC Sticking or other ETC faults Verify if the lift truck was motored down a steep grade
572	**MediumOverspeed** Engine speed has exceeded the second level (2 of 3) of overspeed protection	(1) TurnOnMil (2) MediumRevLimit	Usually associated with additional ETC faults • Check for ETC Sticking or other ETC faults Verify if the vehicle was motored down a steep grade
573	**SoftOverspeed** Engine speed has exceeded the first level (1 of 3) of overspeed protection	(1) TurnOnMil (2) SoftRevLimit	Usually associated with additional ETC faults • Check for ETC Sticking or other ETC faults Verify if the vehicle was motored down a steep grade
611 (61)	**APP1RangeLow** APP_1 sensor voltage out of range low, normally set if the APP_1 signal has shorted to ground, circuit has opened or sensor has failed	(1) TurnOnMil (2) CheckEngineLight	Check foot pedal connector • Check APP_1 signal at SECM PIN B7

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
612 (65**)**	**APP2RangeLow** APP_2 sensor voltage out of range low, normally set if the APP_2 signal has shorted to ground, circuit has opened or sensor has failed	TurnOnMil	Check foot pedal connector • Check APP_2 signal at SECM PIN B16
621 (62)	**APP1RangeHigh** APP_1 sensor voltage out of range high, normally set if the APP_1 signal has shorted to power or the ground for the sensor has opened	(1) TurnOnMil (2) CheckEngine Light	Check foot pedal connector • Check APP_1 signal at SECM PIN B7
622 (66)	**APP2RangeHigh** APP_2 sensor voltage out of range high, normally set if the APP_2 signal has shorted to power or the ground for the sensor has opened	TurnOnMil	Check foot pedal connector • Check APP_2 signal at SECM PIN B16
631 (63)	**APP1AdaptLoMin** Learned idle value of APP_1 sensor range lower than expected	None	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7
632 (67)	**APP2AdaptLoMin** Learned idle value of APP_2 sensor range lower than expected	None	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_2 signal at SECM Pin B16
641 (64)	**APP1AdaptHiMax** Learned full pedal value of APP_1 sensor range higher than expected	None	N/A
642 (68)	**APP2AdaptHiMax** Learned full pedal value of APP_2 sensor range higher than expected	None	N/A
651	**APP1AdaptHiMin** Learned full pedal value of APP_1 sensor range lower than expected	None	N/A
652	**APP2AdaptHiMin** Learned full pedal value of APP_2 sensor range lower than expected	None	N/A
661	**APP1AdaptLoMax** Learned idle value of APP_1 sensor range higher than expected	None	N/A
662	**APP2AdaptLoMax** Learned idle value of APP_2 sensor range higher than expected	None	N/A

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
691 (69)	**APP_Sensors_Conflict** APP position sensors do no not track well, intermittent connections to APP or defective pedal assembly	1) TurnOnMil (2) Level1PowerLimit	Check APP connector and pins for corrosion • Cycle the pedal several times and check APP_1 signal at SECM Pin B7 • Cycle the pedal several times and check APP_2 signal at SECM Pin B16
711 (71)	**LSDFault_Dither1** Dither Valve 1 Fault, signal has opened or shorted to ground or power or defective dither 1 valve	TurnOnMil	Check FTV_1 for an open wire or FTV connector being disconnected FTV_1 Pin 1 (signal) to SECM Pin A1 FTV_1 Pin 2 (power) to SECM (DRVP) Pin A23 Check FTV_1 for an open coil by disconnecting the FTV connector and measuring the resistance (~26Ω ± 2Ω)
712	**LSDFault_Dither2** Dither Valve 2 Fault, signal has opened or shorted to ground or power or defective dither 2 valve	TurnOnMil	Check FTV_2 for an open wire or FTV connector being disconnected or signal shorted to GND FTV_2 Pin 1 (signal) to SECM Pin A2 FTV_2 Pin 2 (power) to SECM (DRVP) Pin A23 Check FTV_2 for an open coil by disconnecting the FTV connector and measuring the resistance (~26Ω ± 2Ω)
715	**LSDFault_CrankDisable** Crank Disable Fault, signal has opened or shorted to ground or power or defective crank disable relay	None	N/A
717	**LSDFault_LockOff** Fuel lock off Valve Fault, signal has opened or shorted to ground or power or defective Fuel lock off valve	TurnOnMil	Check fuel lock off valve for an open wire or connector being disconnected or signal shorted to GND Lockoff Pin B (signal) to SECM Pin A11 Lockoff Pin A (power) to SECM (DRVP) Pin A23 Check CSV for an open coil by disconnecting the CSV connector and measuring the resistance (~26Ω ± 3Ω)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
718	**LSDFault_MIL** Malfunction Indicator Lamp Fault, signal has opened or shorted to ground or power or defective MIL lamp	None	Check MIL lamp for an open wire or short to GND.
721 (72)	**GasFuelAdaptRangeLo** In LPG mode, system had to adapt rich more than expected	TurnOnMil	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose Check for missing orifice(s).
731 (73)	**GasFuelAdaptRangeHi** In LPG mode, system had to adapt lean more than expected	TurnOnMil	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).
741 (74)	**GasO2NotActive** Pre-catalyst O_2 sensor inactive on LPG, open O_2 sensor signal or heater leads, defective O_2 sensor	(1) TurnOnMil (2) DisableGas O2Ctrl	Check that Pre-catalyst O_2 sensor connections are OK. O_2 (signal) Pin B to SECM Pin B13 O_2 Pin C (GND) to SECM (DRVG GND) Pins A16, B17 O_2 Pin 1 (power) to SECM (DRVP + 12V) Pin A23 Verify O_2 sensor heater circuit is operating by measuring heater resistance ($2.1\Omega \pm 0.4\Omega$) O_2 Pin C (GND) to Pin D (power)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
742	**GasPostO2NotActive** Post-catalyst O_2 sensor inactive on LPG, open O_2 sensor signal or heater leads, defective O_2 sensor.	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Check that Post-catalyst O_2 sensor connections are OK. O_2 (signal) Pin B to SECM Pin B19 O_2 Pin C (GND) to SECM (DRVG GND) Pins A16, B17 O_2 Pin D (power) to Post O_2 Heater Relay. Relay pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O_2 Heater Relay has SECM (DRVP + 12V) applied to the relay coil power. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O_2 heater. Verify O_2 sensor heater circuit is operating by measuring heater resistance ($2.1\Omega \pm 0.4\Omega$) O_2 Pin C (GND) to Pin D (power)
743	**Reserved**		
751	**GasO2FailedLean** Pre-catalyst O_2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl	Check for vacuum leaks. Check fuel trim valves, e.g. leaking valve or hose. Check for missing orifice(s).
752	**GasPostO2FailedLean** Post-catalyst O_2 sensor indicates extended lean operation on LPG	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Correct other faults that may contribute to 752 (e.g. faults pertaining to fuel trim valves, Pre-Cat O_2, Post Cat O_2 sensor) Check for vacuum leaks Check for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).
771 (77)	**GasO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGas O2Ctrl	Check fuel trim valves, e.g. plugged valve or hose. Check for plugged orifice(s).

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
772	**GasPostO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on LPG	(1) TurnOnMil (2) DisableGasPost O2Ctrl	Correct other faults that may contribute to 772 (e.g. faults pertaining to FTVs, Pre-Cat O_2, Post Cat O_2 sensor) Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 742 corrective actions).
821	**LiqFuelAdaptRangeHi** In Gasoline mode, system had to adapt lean more than expected	TurnOnMil	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector.
831	**LiqFuelAdaptRangeLow** In Gasoline mode, system had to adapt rich more than expected	TurnOnMil	Low gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector.
841	**LiqO2NotActive** Pre-catalyst O_2 sensor inactive on gasoline, open O2 sensor signal or heater leads, defective O2 sensor	(1) TurnOnMil (2) DisableLiquid O2Ctrl	Check that Pre-catalyst O_2 sensor connections are OK. O_2 (signal) Pin B to SECM Pin B13 O_2 Pin C (GND) to SECM (DRVG GNG) Pins A16, B17 O_2 Pin D (power) to SECM (DRVP + 12V) PIN A23 Verify O_2 sensor heater circuit is operating by measuring heater resistance ($2.1\Omega \pm 0.4\Omega$) O_2 Pin C (GND) to Pin D (power)

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
842	**LiqPostO2NotActive** Post-catalyst O_2 sensor inactive on gasoline, open O_2 sensor signal or heater leads, defective O_2 sensor.	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Check that Post-catalyst O_2 sensor connections are OK. O_2 (sensor GND) Pin A to SECM Pin B1 O_2 Pin C (GND) to SECM (DRVG GND) Pins A16, B17 O_2 Pin D (power) to Post O_2 Heater Relay. Relay pin 87. This relay only turns on after engine has been running for some time and SECM has calculated that water condensation in exhaust has been removed by exhaust heat. Post O_2 Heater Relay has SECM (DRVP + 12V) applied to the relay coil power. The relay coil ground is controlled by SECM Pin A20 to activate the relay to flow current through the post O_2 heater. Verify O_2 sensor heater circuit is operating by measuring heater resistance (2.1Ω ± 0.4Ω) O_2 Pin C (GND) to Pin D (power)
843	Reserved		
851	**LiqO2FailedLean** Pre-catalyst O_2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl	Check for vacuum leaks. Low gasoline fuel pressure, perform gasoline pressure test. Injector problems, e.g. plugged, defective injector
852	**LiqPostO2FailedLean** Post-catalyst O_2 sensor indicates extended lean operation on gasoline	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Correct other faults that may contribute to 852 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O_2, Post Cat O_2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).
871	**LiqO2FailedRich** Pre-catalyst O_2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiquid O2Ctrl	High gasoline fuel pressure, perform gasoline pressure test Injector problems, e.g. leaking, defective injector

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
872	**LiqPostO2FailedRich** Post-catalyst O_2 sensor indicates extended rich operation on gasoline	(1) TurnOnMil (2) DisableLiqPost O2Ctrl	Correct other faults that may contribute to 872 (e.g. faults pertaining to Injectors, MAP, IAT, Pre-Cat O_2, Post Cat O_2 sensor. Look for leaks in exhaust, catalytic converter, HEGO sensors; repair leaks. Check all sensor connections (see fault 842 corrective actions).
911	**O2RangeLow** Pre-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O_2 sensor installed before the catalyst is shorted to GND or sensor GND. O_2 (signal) Pin B to SECM Pin B13 SECM (DRVG GND) Pins A16, B17 SECM (sensor GND) Pin B1
912	**O2_PostCatRangeLow** Post-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) Disable Gasoline Post-catalyst O2Ctrl (3) Disable LPG Post-catalyst O2Ctrl	Check if O_2 installed after the catalyst sensor is shorted to GND or sensor GND. O_2 (signal) Pin B to SECM Pin B19 Possible sources: SECM (DRVG GND) Pins A16, B17 and SECM (sensor GND) Pin B1
921	**O2RangeHigh** Pre-catalyst O2 sensor voltage out of range high, sensor signal shorted to power	(1) TurnOnMil (2) DisableLiquid O2Ctrl (3) DisableGas O2Ctrl	Check if O_2 sensor installed before catalyst is shorted to +5Vdc or battery. O_2 (signal) Pin B to SECM Pin B13 SECM (PWR) Pin B24 SECM (power) Pin A23
922	**O2_PostCatRangeHigh** Post-catalyst O_2 sensor voltage out of range low, sensor signal shorted to ground	(1) TurnOnMil (2) Disable Gasoline Post-catalyst O2Ctrl (3) Disable LPG Post-catalyst O2Ctrl	Check if O_2 sensor installed after catalyst is shorted to +5Vdc or battery. O_2 (signal) Pin B to SECM Pin B19 Possible voltage sources: SECM (PWR) Pin B24 and SECM (power) Pin A23
931	**FuelTempRangeLow** Fuel Temperature Sensor Input is Low, normally set if the fuel temperature sensor wire has shorted to chassis ground or the sensor has failed.	TurnOnMil	Check fuel temp sensor connector and wiring for a short to GND SECM (signal) Pin B14 to FTS Pin 1 SECM (sensor GND) Pin B1 to FTS Pin 2 SECM (GND) Pin A16, B17

(*) Fault actions shown are default values specified by the OEM.

Table 2. Diagnostic Fault Codes (Flash Codes) cont'd.

DFC (MI-04)	PROBABLE FAULT	FAULT ACTION *	CORRECTIVE ACTION FIRST CHECK
932	**FuelTempRangeHigh** Fuel Temperature Sensor Input is High normally set if the fuel temperature sensor wire has been disconnected or the circuit has opened to the SECM.	TurnOnMil	Check if fuel temp sensor connector is disconnected or for an open FTS circuit SECM (signal) Pin B14 to FTS Pin 1 SECM (sensor GND) Pin B1 to FTS Pin 2
991	**ServiceFault1** Service Interval 1 has been reached	None	Perform service procedure related to Service Interval 1 (determined by OEM)
992	**ServiceFault2** Service Interval 2 has been reached	None	Perform service procedure related to Service Interval 2 (determined by OEM)
993	**ServiceFault3** Service Interval 3 has been reached	None	Perform service procedure related to Service Interval 3 (determined by OEM)
994	**ServiceFault4** Service Interval 4 has been reached—replace HEGO sensors	TurnOnMil	Replace Pre-catalyst HEGO sensor Replace Post-catalyst HEGO sensor
995	**ServiceFault5** Service Interval 5 has been reached	TurnOnMil	Perform service procedure related to Service Interval 5 (determined by OEM)

(*) Fault actions shown are default values specified by the OEM.

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Chapter 9.
Parts Description

Fuel System Components for 3.0L Engines

The chart below lists the MI-07 components required for 3.0L engines. Components shown with part numbers are supplied by Woodward as part of the MI-07 system package. Components shown with a dot (•) are supplied by customer.

PART NO.	DESCRIPTION	QTY
1751-6068	Engine Control Module (SECM 48-pin)	1
•	Crankshaft Position Sensor	1
•	TMAP Sensor	1
1689-1081	Fuel Temperature Sensor	1
1680-6005	Oxygen Sensors	2
•	Coolant Sensor	1
•	Engine Oil Pressure Switch	1
1309-6019	Fuel Trim Valve	2
•	Ignition Coils	1
1311-1011	Fuel Lock Off Solenoid	1
5233-1018	Regulator	1
8062-1052	CA100 Mixer	1
6945-5001	Throttle-DV-E5 40mm	1

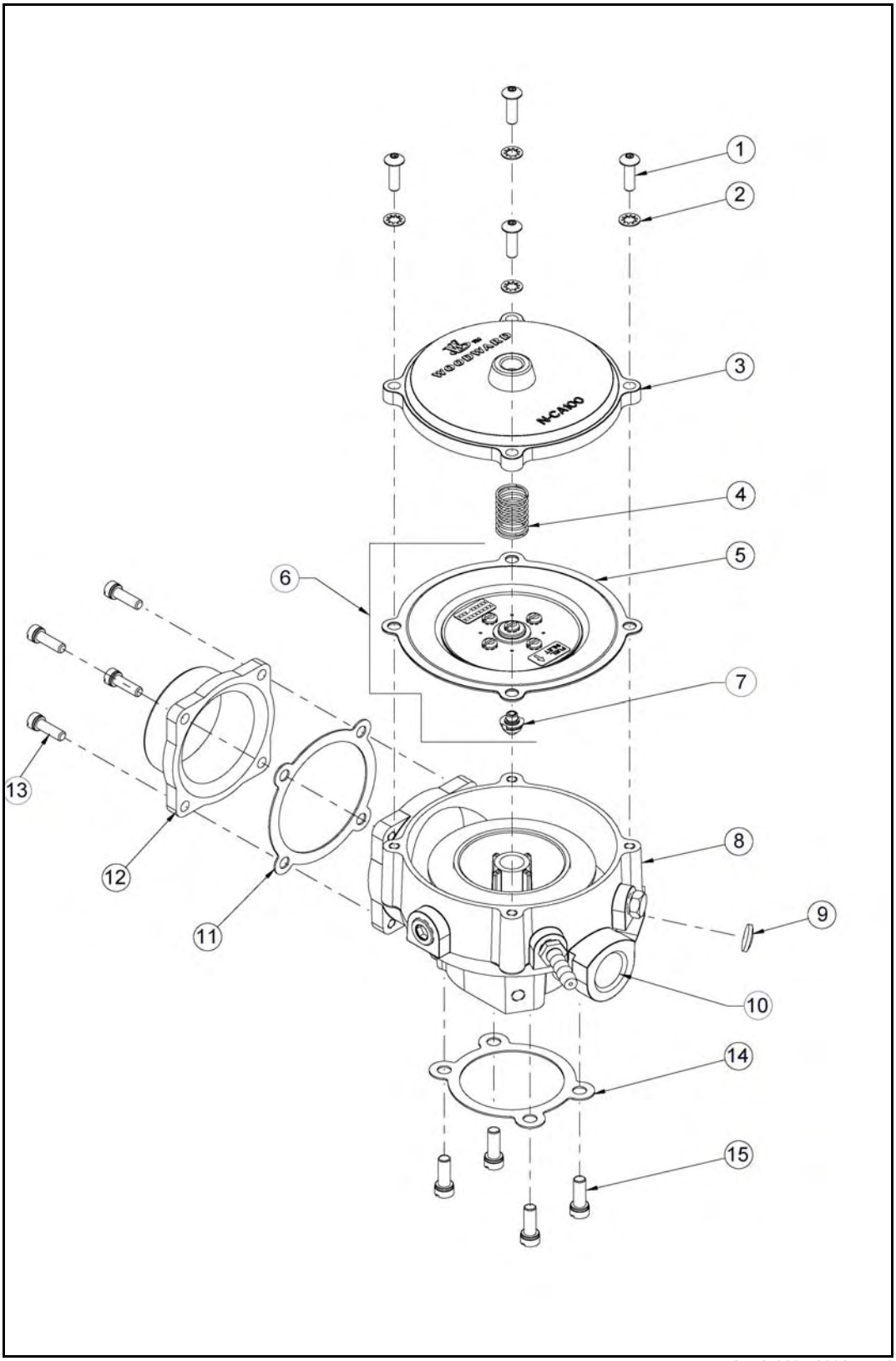
CA100 Mixer

Refer to **Figure 39** exploded view on facing page.

Parts List CA100 Mixer

REF NO.	DESCRIPTION	QTY
1	Torx Screws (T-25) #10-24 x 5/8”	4
2	Lockwashers (T-210) #10 SST	4
3	Mixer Cover	1
4	Mixer Spring	1
5	Diaphragm	1
6	Air Valve Assembly	1
7	Gas Valve Cone (part of air valve assembly)	1
8	Mixer Body	1
9	Expansion Plug Cap Ø 1/2” x 1/16” thick (Ø 12.7mm x 27mm)	1
10	Fuel Inlet	1
11	Air Horn Gasket	1
12	Air Horn Adapter 2-1/16” (52.37mm)	1
13	Fillister Head Screws SEMS Lockwasher 10-24 UNC x 5/8”	4
14	Throttle Body Gasket	1
15	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	4

Exploded View CA100 Mixer



DWG NO 9097-2008 Rev 2

Figure 39. CA100 Certified Mixer Exploded View

N-2007 Regulator

Refer to **Figure 40** exploded view on facing page.

Parts List Regulator

REF NO.	DESCRIPTION	QTY
1	N-2007 Body	1
2	Diaphragm, Primary Assembly	1
3	Springs, Primary Assembly	2
4	Cover, Primary Assembly	1
5	Spring, Secondary Seat, Red	1
6	Dowel Pin Ø 0.094” x 1” L (Ø 2.39mm x 25.4mm L) Hardened Steel	1
7	Diaphragm, Secondary Assembly	1
8	Lever, Secondary	1
9	Seat, Secondary	1
10	Valve Primary	1
11	Fillister Head Screws SEMS Split Lockwasher #12-24 x 5/8”	6
12	Pan Head Screw SEMS Ext. Tooth Lockwasher #12-24 x 1/4”	1
13	Body Gasket	1
14	Back Plate	1
15	O-ring, Size 107 GLT Viton®	1
16	Bottom Plate Gasket	1
17	Plate Cover	1
18	Fillister Head Screws SEMS Split Lockwasher #12-24 x 1-3/8”	6
19	Hex Head Screws SEMS Split Lockwasher 1/4-20 x 5/8”	4
20	Plug, Socket Head Pipe (T-086)	1
21	Cover, Secondary Diaphragm	1
22	Lockwasher, Int. Tooth (T-210) #8 SST	6
23	Torx Screws (T-15) #8-32 x 5/8”	6

Exploded View
P/N 5233-1018 N-2007 Regulator

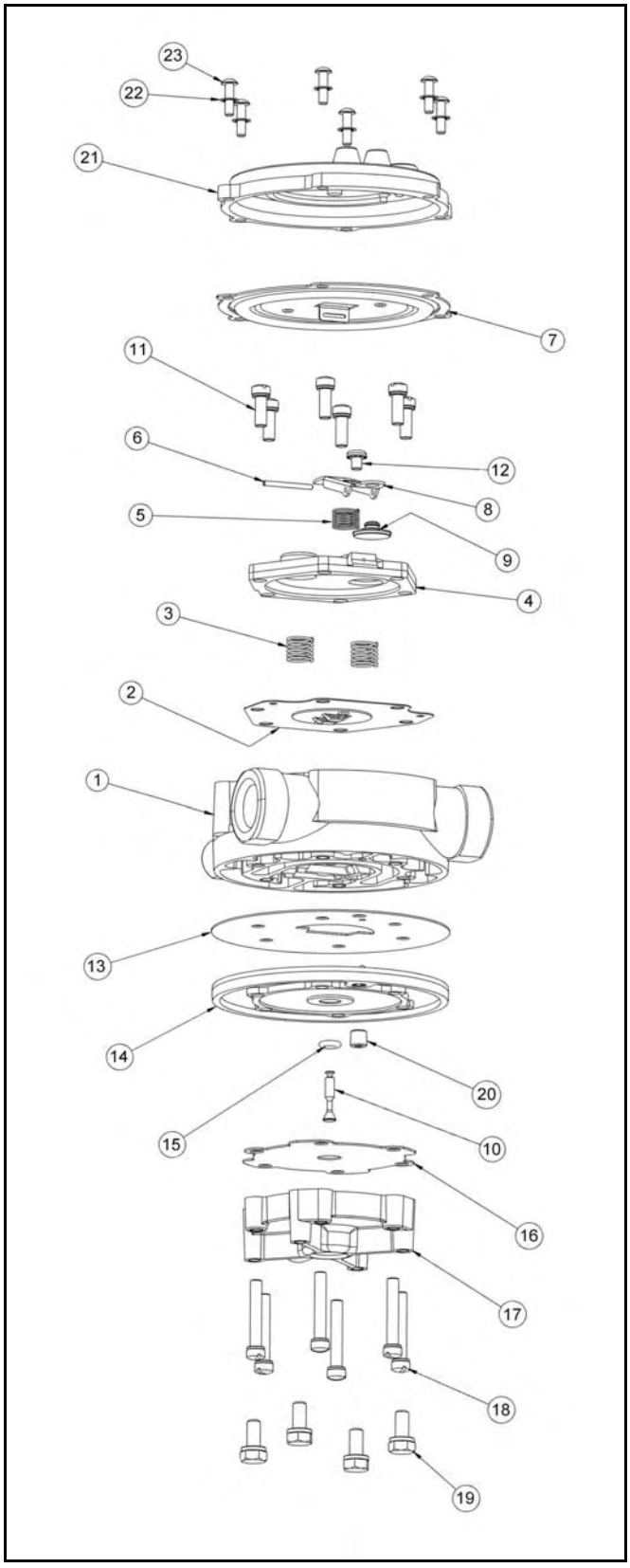


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Figure 40. N-2007 Certified Regulator Exploded View

Appendix

LPG & LPG Fuel Tanks

Liquefied petroleum gas (LPG) consists mainly of propane, propylene, butane, and butylenes in various mixtures. LPG is produced as a by-product of natural gas processing or it can be obtained from crude oil as part of the oil refining process. LPG, like gasoline, is a compound of hydrogen and carbon, commonly called hydrocarbons.

In its natural state, propane is colorless and odorless; an odorant (ethyl mercaptan) is added to the fuel so its presence can be detected. There are currently three grades of propane available in the United States. A propane grade designation of HD5 (not exceeding 5% propylene), is used for internal combustion engines while much higher levels of propylene (HD10) are used as commercial grade propane along with a commercial propane /butane mixture.

APPROXIMATE COMPOSITION OF HD5 PROPANE BY VOLUME

Propane (C3H8)	Propylene	Butane (C4H10)	Iso-Butane	Methane (CH4)	TOTAL
90.0% min.	5% max.	2.0%	1.5%	1.5%	100%

An advantage of LPG is the ability to safely store and transport the product in the liquid state. In the liquid state propane is approximately 270 times as dense as it is in a gaseous form. By pressurizing a container of LPG we can effectively raise the boiling point above -44° F (-42° C), keeping the propane in liquid form. The point at which the liquid becomes a gas (boiling point) depends on the amount of pressure applied to the container.

This process operates similarly to an engine coolant system where water is kept from boiling by pressurizing the system and adding a mixture of glycol. For example, water at normal atmospheric pressure will boil at 212° F (100°) C. If an engine's operating temperature is approximately 230° F (110° C) then the water in an open un-pressurized cooling system would simply boil off into steam, eventually leaving the cooling system empty and overheating the engine. If we install a 10-psig cap on the radiator, pressurizing the cooling system to 10 psig, the boiling point of the water increases to 242° F (117° C), which will cause the water to remain in liquid state at the engine's operating temperature.

The same principle is applied to LPG in a container, commonly referred to as an LPG tank or cylinder. Typically an LPG tank is not filled over 80% capacity to allow for a 20% vapor expansion space. Outside air temperature affects an LPG tank and must be considered when using an LPG system. **Figure A1** shows the relationship between pressure and temperature in a LPG tank at a steady state condition.

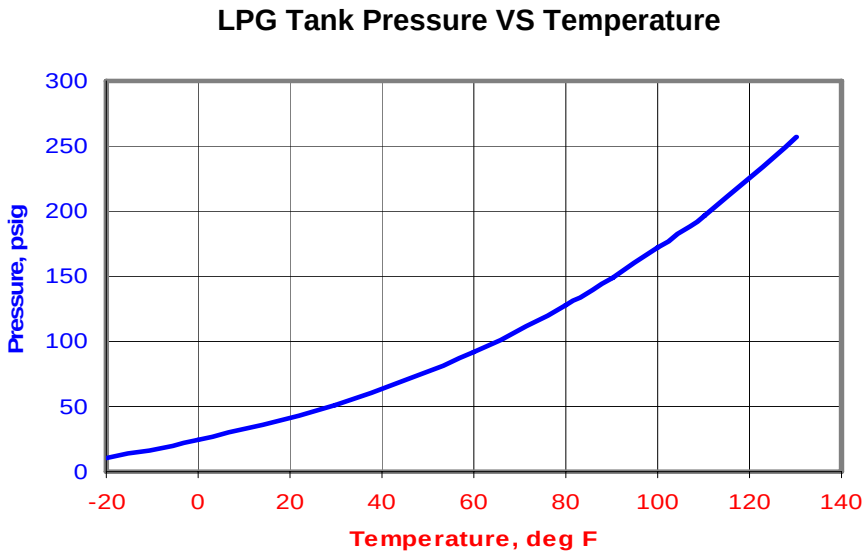
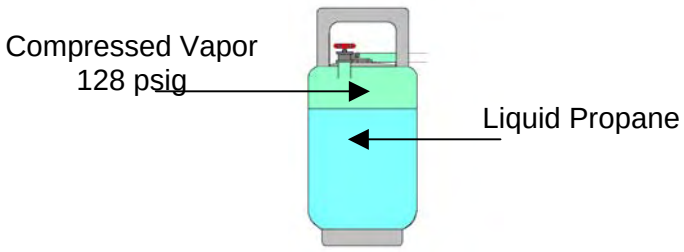


Figure A1. LPG Tank Pressure vs Temperature

With 128 psig vapor pressure acting against the liquid propane, the boiling point has been raised to slightly more than 80° F (27° C).



NOTE

Vapor pressure inside an LPG tank depends on the propane temperature, not the amount of liquid inside the tank. A tank that is 3/4 full of liquid propane at 80°F (27°C) will contain the same vapor pressure as a tank that is only 1/4 full of liquid propane.

LPG's relative ease of vaporization makes it an excellent fuel for low-RPM engines on start-and-stop operations. The more readily a fuel vaporizes, the more complete combustion will be. Because propane has a low boiling point (-44° F [-42° C]), and is a low carbon fuel, engine life can be extended due to less cylinder wall wash down and little, if any, carbon build up.

LPG Fuel Tanks

The two styles of LPG storage containers available for industrial use and lift truck applications are portable universal cylinders and permanently mounted tanks. Portable universal cylinders are used primarily for off-highway vehicles and are constructed in accordance with the DOT-TC (United States Department of Transport – Transport Canada). The cylinders are referred to as universal because they can be mounted in either a vertical or horizontal position (**Figure A2**).

Figure A2. Portable Universal Cylinder

NOTE
A 375-psig relief valve is used on a DOT forklift tank. The relief valve must be replaced with a new valve after the first 12 years and every 10 years thereafter.

The tank must be discarded if the collar is damaged to the point that it can no longer protect the valves. It must also be replaced if the foot ring is bent to the point where the tank will not stand or is easily knocked over.

Installing LPG Fuel Tanks

When installing a tank on a lift truck, the tank must be within the outline of the vehicle to prevent damage to the valves when maneuvering in tight spaces. Horizontal tanks must be installed on the saddle that contains an alignment pin, which matches the hole in the collar of the tank. When the pin is in the hole, the liquid withdrawal tube is positioned to the bottom of the tank. A common problem is that often these guide-pins are broken off, allowing the tank to be mounted in any position. This creates two problems: (1) Exposure of the liquid withdrawal tube to the vapor space may give a false indication that the tank is empty, when actually it is not. (2). The safety relief valve may be immersed in liquid fuel. If for any reason the valve has to vent, venting liquid can cause a serious safety problem.

CAUTION
Exchange empty tank with a pre-filled replacement tank. Wear safety glasses and gloves when exchanging a tank.

LPG Fuel Tank Components

1. Fuel Gauge
2. 80% Stop Bleeder
3. Pressure Relief Valve
4. Service Valve (Tank end male coupling)
5. Filler Valve
6. Alignment Pin
7. Vapor Withdrawal Tube (used only with vapor withdrawal)
8. 80% Limiter Tube
9. Liquid Withdrawal Tube

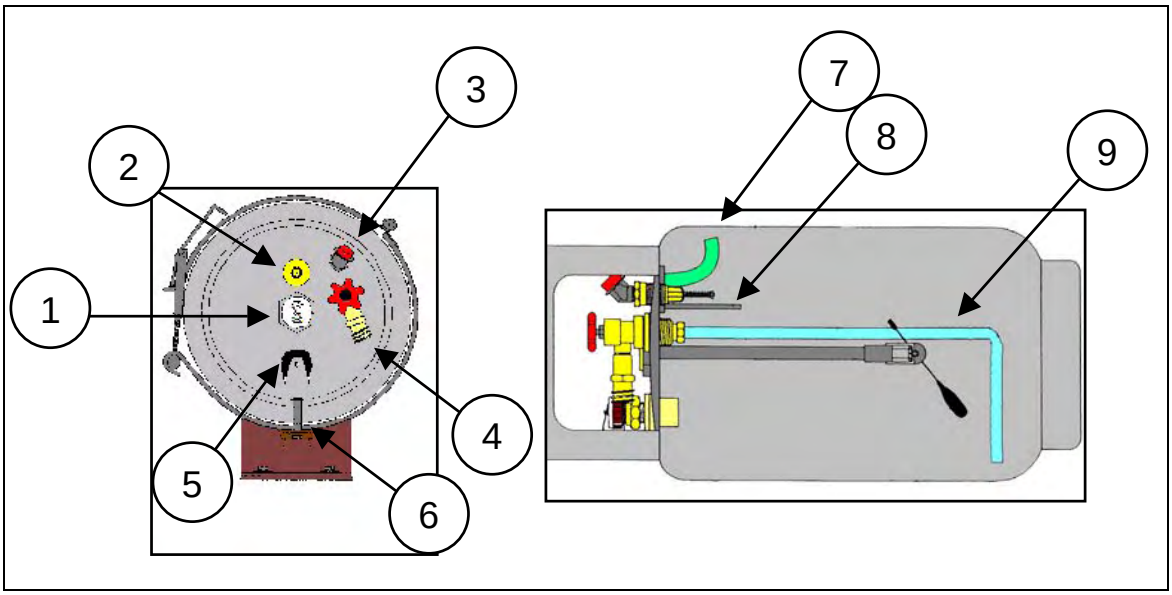


Figure A3. LPG Fuel Tank Components

Fuel Gauge

In **Figure A3** a visual fuel gauge is used to show the fuel level in the tank. A mechanical float mechanism detects the liquid propane level. A magnet on the end of the float shaft moves a magnetic pointer in the fuel gauge. Some units have an electronic sending unit using a variable resistor, installed in place of a gauge for remote monitoring of the fuel level. The gauge may be changed with fuel in the tank. **DO NOT REMOVE THE FOUR LARGE FLANGE BOLTS THAT RETAIN THE FLOAT ASSEMBLY WHEN FUEL IS IN THE TANK!**

WARNING
It is not a legal practice to fill the tank through the liquid contents gauge.

In some applications a fixed tube fuel indicator is used in place of a float mechanism. A fixed tube indicator does not use a gauge and only indicates when the LPG tank is 80% full. The fixed tube indicator is simply a normally closed valve that is opened during refueling by the fueling attendant. When opened

during refueling and the tanks LPG level is below 80%, a small amount of vapor will exit the valve. When the LPG tank level reaches 80% liquid propane will begin exiting the valve in the form of a white mist (Always wear the appropriate protective apparel when refueling LPG cylinders). In order for this type of gauge to be accurate, the tank must be positioned properly. When full (80% LPG) the valve is closed by turning the knurled knob clockwise. Typically a warning label surrounds the fixed tube gauge which reads **STOP FILLING WHEN LIQUID APPEARS.**

Pressure Relief Valve

A pressure relief valve is installed for safety purposes on all LPG tanks. Portable fuel tank safety pressure relief valves are a normally closed spring-loaded valve and are calibrated to open at 375 psig tank pressure. This will allow propane vapor to escape to the atmosphere. When tank pressure drops below the preset value, the valve closes.

Service Valve

The service valve is a manually operated valve using a small hand wheel to open and close the fuel supply to the service line (fuel supply line). The service valve installs directly into the tank and has two main categories, liquid and vapor service valves. Liquid service valves used on portable LPG tanks use a 3/8" (NPT) male pipe thread on the service valve outlet for attachment of a quick disconnect coupler.

An excess flow valve is built into the inlet side of the service valve as a safety device in case of an accidental opening of the service line or damage to the service valve itself. The excess flow valve shuts off the flow of liquid propane if the flow rate of the liquid propane exceeds the maximum flow rate specified by the manufacturer.

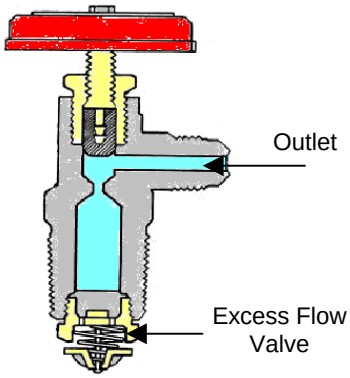


Figure A4. Service Valve

CAUTION

The service valve should be completely open when the tank is in use. If the valve is partly open, the vehicle may not get enough fuel to operate efficiently.

In addition to possibly starving the engine for fuel, a partly open valve may restrict the flow enough to prevent the excess flow valve from closing in the event of a ruptured fuel line.

Most liquid service valves have an internal hydrostatic relief valve and are usually labeled "**LIQUID WITH INTERNAL RELIEF.**" The hydrostatic relief valve protects the fuel service line between the tank and the lock off from over pressurization. The internal hydrostatic relief valve has a minimum opening pressure of 375 psig and a maximum pressure of 500 psig. These relief valves have an advantage over external relief valves because the propane is returned to the tank in the event of an over pressurization instead of venting the propane to the atmosphere.

Quick Disconnect Coupling

The liquid withdrawal or service valve on a DOT tank has male threads and accepts the female portion of a quick disconnect coupling (**Figure A5**). The female portion is adapted to the liquid hose going to the fuel system. Both halves are equipped with 100% shutoffs, which open when coupled together to allow fuel flow. The coupler has two seals. One is an o-ring and the other is a flat washer. The o-ring prevents leakage from the shaft on the other coupling and the flat washer seals when the coupler is fully connected.

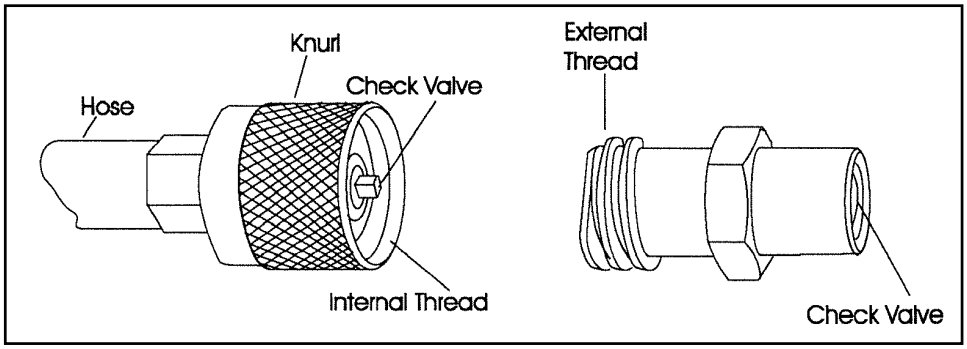


Figure A5. Quick Disconnect Coupling

NOTE
The flat seal and/or the o-ring will sometimes pop off when disconnecting and slide up the shaft of the mating connector, causing the valve not to open when fully mated. Remove the extra washer or o-ring from the shaft and reconnect the coupling.

Filler Valve

The liquid filler valve (**Figure A6**) has a male thread to receive a fuel nozzle and typically has a plastic or brass screw on cap that is retained with a small chain or plastic band to keep debris out of the filler valve. The filler valve is a one-way flow device that uses two check valves to allow fuel to enter the tank but prevent it from exiting. Both check valves are backpressure type check valves, designed so that backpressure from the tank assists the check valves own spring pressure to close the valve. The first valve uses a neoprene on metal seal and the second valve uses a metal on metal seal.

A weakness ring is machined into the filler valve just above the check valves and will allow the filler valve to shear off in case of an accident. The valve will break or shear off above the check valves so that the tank will be sealed and no liquid propane can escape.

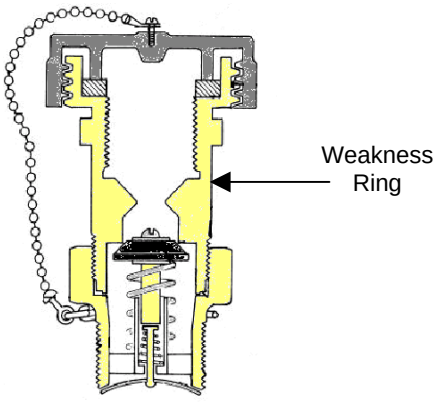


Figure A6. Liquid Filler Valve

Abbreviations

ACFM	Actual cubic feet per minute at the specified suction conditions
AFR	Air fuel ratio
BHP	Brake horsepower
Bi-Fuel	Able to operate on either of two fuels
CTS	Coolant temperature sensor
CNG	Compressed natural gas
Dual Fuel	Able to run simultaneously on two fuels, e.g. diesel and natural gas. Often this term is incorrectly used to describe bi-fuel operation. Spark-ignited engines are typically bi-fuel while compression ignition engines are dual-fuel.
ECM	Engine control module
FPP	Foot pedal position
FPV	Fuel primer valve
FTS	Fuel temperature sensor
FTV	Fuel trim valve
GPM	Gallons per minute of flow
HEGO	Heated exhaust gas oxygen (sensor)
LAT	Limited-angle torque motor
LPG	Liquified petroleum gas
MAP	Manifold absolute pressure
MAT	Manifold air temperature
MIL	Malfunction indicator lamp
MOR	Manufacturer of record for emissions certification on the engine
OEM	Original equipment manufacturer
PHI	Relative fuel-air ratio or percent of stoichiometric fuel (actual fuel-air ratio / stoichiometric fuel-air ratio)
RPM	Revolutions per minute
SECM	Small engine control module
TMAP	Temperature and manifold absolute pressure
TPS	Throttle position sensor
VDC	Voltage of direct current type
VE	Volumetric efficiency
WOT	Wide open throttle

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